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Edited by
R. H. RASTALL and O. M. B. BULMAN

assisted by

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GEOLOGICAL MAGAZINE

VOL. LXXXVI. No. 3. MAY–JUNE, 1949

Shore Platforms

By E. SHERBON HILLS

(PLATES V–VII)

ABSTRACT

The use of the terms " normal " and " abnormal " in relation to shore-platforms has led to confusion and should be discontinued. Processes operative in the formation of shore platforms are analysed from Victorian examples. The effects of water-layer weathering, growth of marine organisms, breakers, and waves of translation on sheltered and open coasts and on various rocks (including a special study of platforms in aeolianites) are discussed.

INTRODUCTION

SHORE platforms are notable features of most rocky coasts, but few and scant references to them are to be found in the early physiographic literature, including the classic works of Fenneman (1902) and Douglas Johnson (1919) on shore processes. Briefly, the major problem presented by platforms about or above mean sea-level is why they should form at all, when it is obvious from the fact that they may be deeply channelled and pot-holed, that the sea is well capable of strong erosion below their level. It is now recognized that many shore platforms do not conform to the profile of equilibrium propounded by Fenneman and Johnson, and that factors other than those involved in the formation of the profile of equilibrium must operate to produce such platforms. Interest in the subject has been stimulated in Australia and the Pacific region because of the inferences that have been drawn from the existence of platforms above the level of the profile of equilibrium, as to recent emergence of the land relative to sea-level, and references to this aspect of the subject will be found in the works of Bartrum, Wentworth, Jutson, and Johnson, listed below.

TYPES OF SHORE PLATFORMS

In the classic discussions of the British school on the potency of marine erosion to produce plains of denudation, various levels were given for the depth at which marine planation occurs, and the attitude of shore platforms in relation to the submarine plain of denudation was not, so far as I can discover, clearly defined. Geikie's statement

that the ultimate level of marine sculpturing is the lower limit of wave action (1885) does, however, imply that shore platforms about mean sea-level must be higher than this. Kinahan (*fide* de Lapparent, 1906) recorded the existence at Inishmore of a series of shore platforms at elevations both above and below mean sea-level, which he explained as being the result of wave action at high equinoctial tides, high ordinary tides, low ordinary tides, and low equinoctial tides respectively. This explanation appears to have in it the germ of ideas expressed by later writers as to the formation of platforms at various levels as a result of normal physiographic processes. De Lapparent (1906) has illustrated a feature that is also stressed by later workers—that the seaward edge of a shore platform is usually marked by a " low tide cliff ". Fenneman (1902) and Johnson (1919) do not refer to details such as these in connection with the concept of the " normal profile " or " profile of equilibrium ". Johnson's well-known diagrams show clearly that in this hypothetical profile the platform exposed between high and low water levels at the stage of maturity is part of a smooth profile extending out from the base of the cliffs first as the " cut terrace " and beyond this as the " built terrace ", at the depth to which wave action has been effective up to the time considered. Shore platforms are represented in younger stages of erosion as transient features only, undergoing progressive reduction in level as erosion approaches maturity.

In 1916, however, Bartrum had already described rock platforms in New Zealand (including the " Old Hat " referred to by Dana (1880) as disturbing the " normal shore profile " of Fenneman, and later (1926, 1935) he specifically designated this and certain other types of shore platforms as " abnormal ", but made the reservation (1935) that he " continues to believe, nevertheless, that they are in truth by no means abnormal, but must be regarded as an expectable consequence of shore-line erosion wherever local conditions comply with certain requirements " (see also Bartrum, 1926, p. 793).

According to Bartrum, platforms of the Old Hat type result from the progressive destruction of the cliff face by subaerial erosion down to the level of permanent saturation (a little below mean high-water level), while weak waves remove the products of disintegration. The seaward edge of the platform is marked by a drop of a few feet to a surface which is regarded as part of the normal shore profile carved from more resistant unweathered rocks below high-water level.

The second type of shore platform classed as " abnormal " by Bartrum is termed by him " storm-wave platforms " (1924, 1926). These are described as being narrow benches often developed at a height of a few feet above high-water level, as a result of the action of storm waves. There is an abrupt descent at their seaward edge into water which is several feet deep at low tide, due to the waves attempting

to " reproduce the normal shore profile under normal conditions or at lower stages of the tide ".

Subsequently, incorporating the results of further observations, Bartrum (1935) has listed the characteristics of storm-wave platforms as follows :—

(*a*) Surface—from about normal high-water level to a few feet above this.

(*b*) Found only where wave attack is vigorous.

(*c*) Cliffs commonly overhang the platforms, showing no sign of weathering. Cliffs attacked during storms.

(*d*) Bench frequently truncates inclined strata.

(*e*) Surface generally moderately irregular near seaward end of headlands, but baywards tends to become almost a plane, because of modification of the wave-cut bench by a subsequent different process.

(*f*) Sea generally shallow—oncoming waves break before reaching the platform.

(*g*) Vigorous kelp is generally attached to steep outer slope and appears to assist in its preservation.

(*h*) Surfaces are typically free from debris except for recent rock-falls.

(*i*) Perhaps a considerable tidal range is a helpful genetic factor.

Bartrum also suggests the hypothesis in this paper that storm-wave platforms may be reduced by secondary subaerial planation to remarkably plane surfaces, in some places above normal high-water level, elsewhere below this, so that by a continuation of storm-wave attack weathering, and removal of weathered rock by waves both weak and strong, platforms with various degrees of perfection as planes may be formed from some feet above high-water mark to a level between between high and low-water.

Were it not that Jutson has consistently applied the term " normal " to shore platforms having the characteristics of some of those described by Bartrum—that is developing between low- and high-water level and having a steep drop of a few feet at the off-shore edge—there would be little need to consider the applicability of the terms " normal " and " abnormal " in connection with shore platforms, since Bartrum gives more specific terms for the " abnormal " platforms and this latter term could conveniently be dropped.

Jutson (1940) recognizes the following platforms along the shores described by him, from above downwards :—

(*a*) " High-level " platforms—average height about 3 feet above the normal platforms, but not constant. Many portions of this platform are awash at mean high tide, other parts are covered only by exceptionally high seas.

(*b*) The " Normal platform "—exposed between mean low tide and mean high tide.

(*c*) The " Ultimate platform "—well below low water level. This is regarded as part of the " normal profile " of Fenneman, and Jutson recognizes that it may in time be further reduced by erosion, or covered with detritus.

If a normal platform is not developed at all then the ultimate platform is developed as a primary feature and is termed the primary ultimate platform ; where the normal platform is present, the ultimate platform is developed as a result of encroachment on the outer edge of the normal platform, and is then termed the " secondary ultimate platform ".

Edwards (1941 a, b ; 1942, 1945) has described shore platforms along the coast of Victoria and Tasmania as storm-wave platforms in Bartrum's sense, rejecting Jutson's terms as unsuitable. On the other hand, Wentworth (1938, 1939) does not appear to subscribe to Bartrum's conception of the development of sub-horizontal platforms above high-water level by wave action alone, and the present writer does not accept as storm-wave platforms several of the features so described by Edwards, as will be explained below.

To be acceptable, a physiographic term should relate to a clearly defined set of conditions and processes, so that the genesis of a feature designated by the term shall be understood. Jutson's terms are, however, largely descriptive and therefore highly subjective. While the writer would agree that a platform about mean sea-level is most commonly developed along coasts, such platforms are, he believes, not always formed in the same way. Furthermore, as Jutson admits, such platforms are not everywhere developed, although the conditions of rocks and waves may not be abnormal where they are absent. Again, this is not the only level at which platforms may develop by normal physiographic processes. For these reasons it is not proposed to use the term " normal platform " ; it is also suggested that the term, " abnormal platform ", if used at all, had best be applied to such as cannot be explained by processes acting at the place under consideration during the present time. An abnormal platform might be a raised platform, or one formed under conditions of tide, of wind, or of some other factor, differing from those now obtaining. The term " ultimate platform " is almost synonymous with Fenneman's " normal profile of equilibrium ", except that the latter is more properly applicable to a cross-section of a coast, and its use introduces a further complexity with regard to the word " normal ". For this reason, and because the ultimate platform is in fact subject to further reduction in level by prolonged erosion and is therefore not the ultimate level of marine planation, use of the term is not favoured.

It is hoped that a nomenclature based on genetic conceptions, as partially outlined by Wentworth (1938, 1939), may eventually be arrived at.

Processes in Platform-Development

Before considering the general question of wave attack on a rocky shore, the effects of other processes should first be dealt with, so that such effects may be recognized and excluded from the analysis of wave action.

Water-level weathering.

This process was first described by Bartrum and Turner (1928) and later by Bartrum (1935). It was subsequently named and more completely analysed by Wentworth (1938, 1939). Weathering of rock exposed above the level of water standing in very shallow pools results in well-nigh plane, level surfaces, formed at various elevations between low- and high-water level, and even several feet above high-water level in places where splash and spray can lodge. The location of pools is primarily determined by some other agent, either wave action or subaerial erosion. Johnson (1938) has raised objections to the term because of possible confusion with sea-level. Wentworth's term refers to the various levels in different shallow pools or puddles, which are simply layers of water, and it may therefore be preferable to use the term "water-layer weathering", instead of "water-level weathering", which latter term should, I agree, be reserved for weathering related to the general level of the sea and of ground water in the immediate vicinity of the shore, as in platforms of the Old Hat type.

The process is admirably demonstrated along the Victorian coast, but is much more important in certain rocks than in others. In the districts studied, Jurassic felspathic sandstones and shales, Tertiary basalts and basalt tuffs, and Tertiary ferruginous sandstones have been most affected. On exposed coasts splash and spray pools many feet above high-water mark develop horizontal water-layered surfaces, in places several square yards in area, which are particularly common on the exposed southern coast of the San Remo Peninsula in the Jurassic sandstones and shales (Plate V). As noted by Edwards (1942), the joints in these rocks are often hardened by deposits of limonite, and an extensive water-layer will then consist of a series of more or less isolated puddles, each developing on a joint-block, and having a rim a fraction of an inch high consisting of the limonite-indurated rock, or simply limonite. Water layers occurring well out of reach of direct wave attack by virtue either of their elevation or of protection among the crags of the cliffs are identical, except in their smaller size, with those that are awash at high tide, and the rapid fretting by alternate wetting and drying of rock rising above the pools is readily verifiable in the field.

In slightly weathered Tertiary basalts on Phillip Island, a series of stages in water-layer weathering is observable (for example, at Smith's Beach) in which the general level of the sea is dominant because of open jointing in the rocks. The basalt is polygonally jointed, and the joint planes, being occupied by water between low- and high-water level, typically weather to an open, smooth, U-shaped section, in which the water occupies the bottom of the U, often only in the actual joint plane itself (Plate VI, fig. 1). The rock immediately adjacent to the water is repeatedly wetted by splash from ripples and dried in the air, so that it disintegrates and the troughs thus broaden. At their edges the walls are undercut for an inch or so in many instances. At the intersection of joint planes, at first small, and later large water-layered surfaces form, and because of intercommunication between the joints the level of the weathered troughs may be the same over areas of several square yards. Residuals of basalt remain between the joints, having rough surfaces that are attacked by the waves mainly by quarrying and to a lesser degree by abrasion. Places from which freshly removed joint blocks have gone are easily recognizable. It is clear from the fact that the water-layer weathered troughs are equally well developed in all the various directions that the joints take, whether protected or not by upstanding residuals of basalt, that neither swash nor plunge of waves is primarily responsible for their formation, although the channels are kept clear of detritus by the swash that travels along them. The delicate undercutting of edges at a well-defined level is, however, a clear indication that erosion by surging water is subordinate to weathering in forming the troughs.

Influence of rock type in water-layer weathering.

This process can operate only in rocks that, for one or another reason fret more rapidly under conditions of alternate wetting and drying than when permanently saturated. On Smith's Beach, for instance, a large residual of quartzite (representing silicified interbasaltic sand) rises sharply above the basaltic shore platform. The quartzite is virtually unaffected by sub-aerial weathering and therefore shows no effects due to water-layer action at all. At the same locality, too, strike ridges and other masses of " harder " basalt rise a few feet above the level of rocks that have been perfectly levelled off (Plate VI, fig. 2). Edwards (1941) and Jutson (1940) have pointed out that shore platforms are very imperfectly developed in fresh granites in southern Victoria, whereas it is known (Hills, 1940 ; Jutson, 1940) that they are well-formed in weathered granite. I take it that, to the extent that water-layer weathering may be involved on these granitic coasts, the process would be very slow in the fresh rock but would readily affect that in which the felspars were kaolinized.

Effects of marine organisms.

It is notable that on many parts of the Victorian coast growth of marine plants and animals is so profuse as to form an almost uninterrupted cover to rock surfaces below a certain level, which is usually quite sharply defined. Above this level the rocks are bare or have organisms very sparsely attached, usually in crannies or holes that retain water. The actual level concerned is usually about mean sea-level, although it may vary according to local conditions of porosity of the rocks, vigour of waves, and also with different organisms. Where a shore platform is affected by water-layer or water-level weathering, but has residuals rising above the level surfaces, it may be observed that the highest widespread levelling corresponds with the upper limit of profuse growth of organisms that presumably require perpetual moisture in the rocks in order to survive. Higher water-layered surfaces may occur, but these will usually be small and will occur only where the tightness of the rocks or the high range of splash permits the formation of local pools which form on top of the patches of tight rock. On platforms between high- and low-water level, the sea grape (*Hormosira*), mussel colonies, and other growths, may form a mat over which it is difficult to walk (see Plate VII, fig. 1). Such a mat, indicating as it must at least approximately the level of permanent saturation below which water-layer weathering cannot operate effectively, has also an important effect in protecting the platform from abrasion, for boulders moved over it by the waves may not come in contact with the rock at all where the growth is dense. Protection is also afforded from wave quarrying due to the plunge of breakers, and it is indeed obvious from the great width of platforms (in many places over 100 yards wide, and often 200 yards) that wave attack on their surfaces, once they are formed, is entirely subordinate.

A further effect of such growths is to protect the rock from drying, even on the surface skin, at low tide. Although weathering must be very slow below the level of saturation, it cannot be denied that the surface skin, and small projecting pieces of rock at the edges of crevices or holes will dry out down to low-tide level, especially on hot days. Thus, it is expectable that a platform primarily developed at mean water level would show a gradual slope up from about low-tide level to the upper limit of profuse marine growths, and such a condition is in fact found in most instances (although not with the platforms developed in dune limestone, described below). Another effect which would contribute to the formation of a gently sloping platform would be wave action on the platform (as distinct from the attack on its seaward edge). The outer parts, being older, would have suffered more prolonged attack and would therefore be lower than the landward zone.

Width and perfection of water-levelled surfaces.

In Victorian examples, shore platforms (again with the exception of those in dune limestone) are broadest and smoothest on sheltered coasts that are not subjected to waves of more than moderate force. On the open coast, which is affected by very strong on-shore gales, platforms are narrower, less regular, and have other features that are to be related to the effects of powerful waves. Platforms on the sheltered coasts, as for instance on Phillip Island between Cat Bay and Ventnor (Plate VI, fig. 3), are up to 200 yards wide, rising very gradually from about low water level to an average of about 3 feet above lower water level, and about 2 to 3 feet below high-water level.[1] On open coasts, strong attack on the seaward edges of the inter-tidal platform is obvious. Great wave-quarried blocks lie in the breakers in places, the edge of the platform is strongly eroded into numerous gulches and chasms, which may extend right through it to the cliff, and observation shows that the breakers pound the edge of the platform, armed with a visible load of pebbles and sand. This attack by swell or forced waves is virtually as effective at low-tide as at high—perhaps more so since the waves break at low-tide on the rocks themselves without an intervening water cushion. Under such conditions the "low-tide cliff" referred to by Bartrum, Jutson, and Edwards is well developed, and marks the seaward edge of the shore platform.

In sheltered waters, on the other hand, wave action is at all times weak, and the great width of the perfectly developed platforms is to be ascribed to the fact that erosion of their seaward edges is very slight. Water-layer weathering, and subaerial weathering of the cliffs, combined with the removal of detritus by the weak waves at high tide, account for the observed features. On such coasts, the total volume of eroded rock is less than on exposed coasts. The retreat of the cliffs, by means of which the platform is widened, takes place partly by subaerial weathering and partly by attack at the base by waves of translation that sweep over the shore platform, in the manner described by Bartrum for shore platforms of the Old Hat type (1926). In most of the Victorian examples, however, as one traverses from an exposed to a sheltered coast, it is seen that platforms in half-sheltered positions (as where the south-west gales are nearly parallel to the shore) are very well developed but have numerous residuals of fresh rock rising above them. It would seem, therefore, that weathering of the cliff face as described by Bartrum for the Old Hat has not been a necessary factor in such instances, although, as in Bartrum's type, it is the level of saturation that is most important in determining the shore platform.

[1] Tide gauges have not been used in this work, and the terms used relate to average tidal conditions as observed on the beaches.

In some localities too, wave attack is less important than subaerial weathering in removing the cliff. The platforms described have, therefore, many features in common with the Old Hat type, but are not precisely similar. Especially it must be noted that the Victorian platforms in sheltered waters, where they are best developed, are closer in their average elevation to mean sea-level than to mean high-water level. In many localities, too, where the rock is clearly weathered in the cliffs, the lower limit of strong weathering is well above mean high-water level. In such instances the weathered rock is stripped off the fresh, leaving a rough platform level that is not at all likely to be confused with the true marine platform. The latter, developed about mean sea-level, often has rather flat-topped residuals, the summit levels of which correspond with the depth of weathering in the cliffs, slightly reduced by subsequent denudation.

Shore Platforms in Dune Limestone

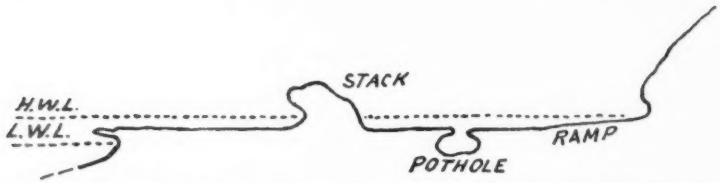
The formation of shore platforms in consolidated Pleistocene calcareous aeolianites has been studied at Point Lonsdale on the western side of the entrance to Port Phillip Bay, and at Sorrento, on the eastern side. The platforms are remarkable for their almost perfectly plane surfaces, marred only by rare residuals, potholes, and chasms, and equally for their horizontality, great breadth, and lateral extent (Plate VII, fig. 1). At Point Lonsdale the platform extends out from the cliffs in the form of a spit for almost a quarter of a mile, broken by deep channels in places and, for this part, ideas as to its formation need not be concerned with detritus supplied from the cliffs.

The platform of this spit differs in no way from those which immediately front the cliffs at Point Lonsdale and at Sorrento. They are all virtually horizontal, with differences of elevation of only a few inches except for the rare, upstanding residuals of dune rock. At the seaward edge there is a sharply defined low-tide cliff, along which great blocks of rock are undermined and fall away (Plate VII, fig. 3). I have not been able to investigate the undercutting of the seaward edge, but along the sides of channels eroded through the platform, ledges of rock 8 to 10 feet wide and only a foot or so thick suggest that the surface of the platform is much more resistant than the rock beneath. This is not an original feature, for the dune bedding lies at all angles to the surface of the platform (Plate VII, fig. 2).

At the landward side, the margin of the horizontal platform is defined with knife-edge precision. The platform, being almost entirely covered with a mat of *Hormosira* weed, mussel colonies, and other growths, ends sharply at a gently sloping bare kerf of hard dune rock, which rises as a typical low ramp to the notch in the cliff or in the rock stacks. The level of the platform is approximately mean sea-level,

and that of the wave notch is about high-tide level or slightly above this, due to the sweep of the waves up the ramp (Text-fig. 1).

At all states of the tide at both localities, except when the waves do not cover the platforms, the latter are swept by waves of translation generated in the breaker zone offshore, and often regenerated when the combers reach the outer edge of the platform. At Point Lonsdale, on the " spit " referred to, the water sweeps across the platform with a speed of 5 to 7 knots, which decreases greatly only when the waves are too low to more than " trickle " over it. Similar conditions obtain at Sorrento, except that the cliffs supply debris to the platform, which has many more patches of sand and small stones than are found on the spit, and a correspondingly weaker growth of organisms.



TEXT-FIG. 1.—Generalized section across the platforms in Calcareous Aeolianite. Not to scale.

At both localities and along the coast as far as studied, the dune limestones become progressively indurated with secondary calcite cement between the grains, as sea-level is approached. Two or three feet above high-water level the rock is soft and crushes under the hammer, but at the level of the wave notch it is hard enough in patches to ring when struck, and below this, on the ramp and the platform, the rock is completely indurated, brittle, and sonorous to a depth of 1 to 2 feet below the level of the platform.

That this induration at sea-level is not to be read in reverse as a decalcification above sea-level is clear, firstly because successive layers of dunes separated by old soil horizons occur, and in cliff sections the differences in colour, texture, and degree of compaction of the layers are everywhere distinct, while the old soils are virtually unaltered from their original condition. Also, since the rocks are aeolianites, the induration of the hard layer at sea-level is obviously due to secondary cementation, and " de-cementation " so neatly achieved as to release again the original grains without giving rise to other solution effects would be a difficult achievement for the agents available.

I would attribute the cementation of the dune rock to the precipitation of calcium carbonate from rain-water percolating through it when the fresh carbonated water meets the sea-water that must, because of the porous nature of the rock, penetrate well beneath the cliff base.

Evidence for the saturation of the rock with sea-water at and just above high-tide level is afforded by the continual dripping of such water from the roofs of undercut ledges and low caves excavated below high-tide mark, even from rocks far removed from spray at low-tide.

Macfadyen (1930), Kuenen (1933), and Umbgrove (1947) have referred to the solvent action of sea-water under tropical conditions, while Wentworth (1939) describes coastal benches as formed by the solution of $CaCO_3$ *above* the level of saturation with sea-water, which itself is believed to be saturated with $CaCO_3$. He describes solution benches as generally 2 to 3 feet, rarely 5 to 6 feet, above mean water level, with a tidal range of less than 3 feet. The platforms herein described differ from solution benches in their lower elevation, being approximately at mean sea-level, and in their actual induration, which makes them harder than the rock both above and below.

In the dune rock, water-layer weathering at elevations above the horizontal platform does not take place, for the rock is so porous that pools will not stand on it above the level of saturation. Being calcareous and porous it is unlikely to be affected by alternate wetting and drying, and its high porosity, too, would perhaps reduce the effect of crystallization of salt in the pores, since the crystals would grow into large cavities, and not much water would remain in any case, to form large crystals. The reduction of residuals on the platform, and attack on the cliffs, is largely to be attributed to wave action by quarrying and abrasion, but once the horizontal platform has been produced it cannot be subject to any significant wave attack on its surface, since it remains horizontal almost to the edge of the low-tide cliff. There, however, irregularities appear due to the action of breakers, whereas the waves that cross the platform, being waves of translation, suffice merely to sweep it clear of detritus.

Behind the bar afforded by the " spit " at Point Lonsdale, numerous platform residuals, appearing above sea-level at low-tide, occur for a mile or more inside Port Phillip Bay and extend for several hundred yards into the Bay, from the beach. All are at the same level, which is also the same as the spit, although in the Bay the waves never attain the size of those on the ocean front. It would appear, therefore, that the level of the indurated layer and hence of the platforms is independent of the nature of wave attack, as would be expected if the bench is formed in a definite position relative to mean sea-level.[1]

Ferruginous Cementation.

The formation of a strong coating, up to an inch or more in thickness,

[1] There is evidence at Sorrento for the uplift of a former indurated platform-level by some 4 to 6 feet. No clear indication of this was noted at Point Lonsdale, and the matter will be dealt with more fully in another context.

of secondary limonite on exposed surfaces about sea-level is common where the original rocks are highly ferruginous. Such coatings have been noted, particularly in the shore platforms near Melbourne, developed from Tertiary ferruginous sands, and also at the Forrest Caves, Phillip Island, developed from basalt tuffs. Large surfaces on the shore platform are coated over, and pebbles and shells incorporated in the ferruginous veneer, which is much harder than the original rock. Even the surfaces of small pot-holes may be so coated. The ferruginous deposits undoubtedly have the effect of preserving the rock surfaces on which they form, and the evidence is that they are deposited mainly between low- and high-water level. A difference in colour of the iron oxide cement in the rocks of the cliffs and the coatings is characteristic, that in the cliff being buff or yellowish-red, and that on platforms very dark brown or black.

Wave Action in Platform-formation

On the Victorian coast, and from examples quoted in the literature, it is clear that, considered broadly, waves attack a rocky coast in a broad belt extending from well below low-water level to several feet above high-water. In the breaker zone erosion is clearly vigorous throughout this belt, so that ideally, wave action alone from this zone to the shore should result in a profile consisting of a submarine shelf below low-water level, sloping up continuously to a wave ramp at the shore, up which the waves of translation sweep. That portion of the wave ramp that is exposed between low- and high-water levels is a type of shore platform, and whether or not a wave notch will develop at the cliff base will depend upon local conditions of the rocks, and vigour of waves.

The actual slope of these features, especially the breadth and inclination of the wave ramp, will also depend upon local conditions. Such a profile is expectable in rocks not subject to special effects of weathering or cementation about sea-level, and is generally found in fresh granite, but the surface exhibits marked irregularity due to minor " accidents " in the erosion of joint blocks.

With soft rocks, subject to the attack of strong waves, erosion below low-tide level would be relatively easy, so that the submarine section of the profile should extend very close to the cliffs, and the wave ramp would then be absent, or replaced by a transitory sandy beach which would be scoured during storms. This is the condition on long stretches of the Victorian coast, where soft Tertiary sedimentary rocks occur (Baker, 1943).

Under the special conditions postulated by Bartrum (1935) of strong waves breaking well off-shore and the combers impinging on a cliff, the

final plunge of the combers would, I suggest, result as usual in a wave ramp rather than a horizontal, plane platform, partly because the formation of such a platform would require maximum erosion at a defined level, which is not expectable with variation in wave height, also because the seaward edge of the platform would surely be more eroded than the landward, and again, because even in a tideless sea with waves of constant height, dissipation of energy in waves of translation requires that they form a ramp sloping seaward.

With rocks susceptible to the special effects of water-layer (and water level) weathering about mean sea-level, however, the above described profile is modified. On those parts subject to splash and spray, or exposed between tide levels, many horizontal areas that are swept mainly by waves of translation or swash at the lower elevations are formed. Weathering tends to reduce rocks standing above the level of saturation and, as described above, broad platforms result especially in relatively sheltered positions where wave attack on the seaward edge is not strong.

The waves of translation that pass over such platforms produce little effect in lowering their elevation, but they do strongly attack the bases of rock stacks and the cliff itself. In such attack, the energy of the wave front is partly expended in an upward surge of the " swash ". Where a platform is narrow and the waves strong, the swash may itself operate over a belt at the foot of the cliffs, up to several feet above the platform, resulting again in a wave ramp.

Where the platform is broad and the waves that reach the cliff are more feeble, the upward swash will be effective only on a gentle ramp, and such a ramp will be formed only in soft rocks that can be readily eroded by the weak waves. This condition obtains in the Pleistocene aeolianites at Point Lonsdale and Sorrento. Rock stacks nearer the outer edge of the platform in these aeolianites are, however, subject to stronger attack by the translatory waves, and their bases have only short, steep ramps, or notches.

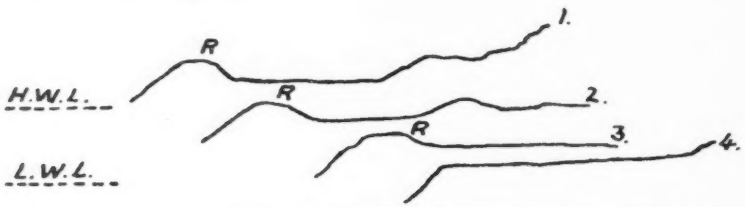
The term " storm-wave " platform is I believe, misleading if it is applied to platforms on open coasts that are subject to severe wave action in the normal course of events, simply because such coasts are also subject to severe storms. Observation indicates that the features of such coasts where they have been studied in Victoria are explicable along the lines indicated in the above discussion, without recourse to the special effects of storm waves, except for minor details. Indeed, much of the destruction of platforms on open coasts must be attributed to storm waves, which have powerful erosive effects over a broad vertical zone.

Bartrum's description of storm-wave platforms includes several factors, but if the concept of wave planation about high-water level or

slightly above is basic to the definition of the type, the writer would not apply the term as Edwards has done to the Victorian examples studied.

Ramparts.

The presence of low ramparts rising above the general level of platforms at their seaward edges has been noted at many localities (Wentworth, 1938 ; Bartrum, 1935 ; Jutson, 1948). Bartrum's and Wentworth's explanation, that the rampart is preserved because it is wetted more continuously than the rocks behind it seems clearly to be correct, and has important implications. For instance, the rampart could persist in spite of erosion at the platform edge, if the rocks behind it are continuously reduced in elevation by water-layer weathering ; but once they are reduced to water level the rampart could no longer be regenerated if once removed by erosion (Text-fig. 2). Systematic study of ramparts would seem, therefore, to offer a delicate test of the relative importance of weathering and marine erosion in platform development.



TEXT-FIG. 2.—Possible stages in the retreat of the seaward edge of a shore platform, retaining a rampart (R) while the platform remains above the level of saturation, but losing it when reduced to that level.

Additional factors.

Most recent work on shore platforms has been done in the Pacific Region, on shores not subject to severe cold or to the peculiar effects of weathering under monsoonal conditions. It is to be expected that where freezing may occur in winter, different effects from those described will be found, as Nansen (1922) has shown, and in regions of low average temperature, too, the effects of alternate wetting and drying, and of crystallization of salt, may be subordinate. Marine growths may also vary in their vertical range according to the local environment and with different types of organisms. Under monsoonal conditions the effects of very deep weathering should also be noticeable in emphasizing the influence of the level of saturation, and observations in other climatic zones should, therefore, yield significant results. Detailed study of the shores of bodies of water with no or very small tidal range would also permit a clearer analysis of shore processes by removing the effect of one important variable in marine erosion.

SHORE PLATFORM AT SAN REMO

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EXPLANATION OF PLATES

PLATE V.—Exposed coast, San Remo, Victoria, in Jurassic sedimentary rocks, at half-tide. In the foreground, a water-layer weathered surface and shallow pool fed by splash, above HWL. Beyond this, a rough platform just above LWL, that is almost always awash ; on this,

large blocks fallen from the cliffs. On the headland, a rough platform with strike ridges of harder rocks rising to HWL.

PLATE VI, FIG. 1.—Joint planes in basalt, Smith's Beach, Phillip Island, with incipient stages of water-level weathering. Note the marine gasteropods and sea-weed on the levelled surfaces, especially in the water.

FIG. 2.—Platform in basalt, Smith's Beach, at low tide. Residuals of basalt rise above the water-levelled surface.

FIG. 3.—Broad shore-platform in moderately sheltered water, Cat Bay, Phillip Island, at low tide.

PLATE VII, FIG. 1.—Shore platform at Point Lonsdale, in calcareous aeolianite, at low spring tide with a calm sea. Looking across Port Phillip Heads to the Sorrento Peninsula. The figures give the scale. Note the dense marine growths on the platform.

FIG. 2.—Deep undercutting of the hard layer that forms the surface of the platform at Point Lonsdale.

FIG. 3.—Block at the seaward edge of the platform at Point Lonsdale, fallen away after undercutting. Low tide.

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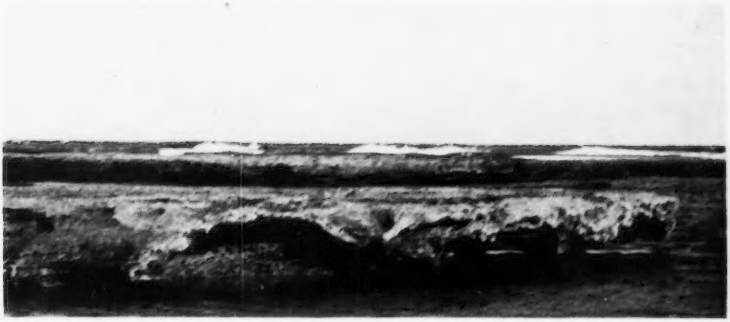
SHORE PLATFORMS ON PHILLIP ISLAND.

1



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SHORE PLATFORMS AT POINT LONSDALE.

On the Genus *Corynoides* Nicholson

By Isles Strachan (Sedgwick Museum)

Abstract

The Ordovician genus *Corynoides* Nicholson has until recently been very imperfectly known and generally neglected. Its development and peculiar morphology are discussed, but its systematic position amongst the graptolites remains doubtful. Four European species are here described and figured, one being new, and American species are briefly discussed.

THE genus *Corynoides*, erected by Nicholson for some problematical fossils associated with graptolites, has been generally neglected by later workers, specimens being referred to the early figured species without adequate examination of their different characters. In the course of some work on Ordovician graptolite faunas I have had occasion to attempt the identification of species of *Corynoides*, and have realized that they were not at all well-defined. At Dr. Bulman's suggestion I have tried to locate and re-examine the types, and to redefine the characters of the recognized species, interpreting them in the light of his recent work whereby the morphology and development of the genus has been elucidated.

I have been fortunate in obtaining material from various sources. I must thank the authorities of the British Museum (Natural History) and the Department of Geology of Aberdeen University for specimens from the Nicholson collections, the Department of Geology of Birmingham University for some from the Lapworth collection, and the Geological Survey in London and Edinburgh for other material. I must also express my grateful thanks to Dr. Bulman for encouragement and advice throughout the work.

Corynoides Nicholson 1867

(*Corynograptus* Hopkinson and Lapworth 1875)

Rhabdosome composed of a long sicula and very few thecae growing parallel to and in contact with it; sicular and thecal apertures each with a broad, lamelliform process. Apparently confined to the Ordovician and recorded from Europe and North America from the Glenkiln-Lower Hartfell Shales and their equivalents.

Genotype: *Corynoides calicularis* Nicholson (monotypy).

The interpretation of the forms referred to this genus has been a matter of considerable difficulty in the past. Nicholson (1867, p. 108) thought that "*Corynoides* has evidently been composed of a single polypite only", and Lapworth held the same view. Roemer (1897, p. 636) suggested that there were several thecae present and associated the genus with *Cephalograptus*, but Ruedemann was the first to describe

a sicula and several thecae (1908, p. 231). His interpretation, which was followed by Hadding (1915, p. 25), has recently been shown to be imperfect by Bulman (1944, p. 24) who, with well-preserved material from limestone nodules, has been able to give a detailed account of the morphology and development.

There is a very close structural similarity in all the species so far described, and they form a distinct group somewhat removed from the rest of the graptolites.

The development has been fully described by Bulman (1944, 1947) but will be summarized here. The prosicula is of the usual graptolite form but is proportionately longer. It is followed by a very long metasicula whose aperture carries a broad, lamelliform virgella, which is quite distinctive but formed in essentially the same way as the normal rod-like virgella of other graptolites. The first theca develops from a bud which is almost apical on the prosicula and grows down beside the sicula to its aperture where it develops a process similar to the virgella. The second theca arises from the first, near its apex, and crosses over to the other side of the sicula when near the distal end. This grouping of the sicular aperture between two thecae with the three projecting processes is the most adult and the commonest stage observed. A third theca has been seen quite frequently in some species. It develops apparently from the second theca but almost immediately grows into a short, free tube projecting at right angles to the rhabdosome length and does not appear to develop into a normal theca. It was this structure which Ruedemann described as the sicula.

The peculiarities of the genus appear to be (1) the small number of thecae, (2) the presence of the broad process on both the sicula and thecae, (3) the apical position on the prosicula of the first thecal foramen, and (4) the alternating origin of the thecae.

The relationships of the genus are obscure. The alternating development of the thecae precludes any affinity to *Azygograptus* as suggested by Ruedemann, since there the thecae develop in series. Apical initial buds have been observed in a few true graptolites, but only at lower stratigraphical horizons. *Isograptus* shows this character, as well as having elongate thecae with broad apertural processes whose structure is at present not known, and *Corynoides* may have arisen from an isograptid ancestor, inheriting also the alternating development of the thecae. Since the peculiar third theca is of fairly frequent occurrence it can hardly be regarded as an abnormality, and Dr. Bulman has suggested that it might possibly represent the bitheca of a dendroid. Ruedemann has also suggested dendroid affinities for the genus, but it would seem better to leave the family *Corynoididae*, as both these authors do, in the Graptoloidea for the present.

Four species have so far been described from Europe, *Corynoides*

calicularis Nicholson, *C. curtus* Lapworth, *C. gracilis* Hopkinson, and *C. incurvus* Hadding. A new species, recorded as such by Peach and Horne in 1899, is described for the first time below.

The author has been unable to find any material of *C. gracilis*; the whereabouts of Hopkinson's originals is unknown and the only specimens labelled as this species, which are in the Geological Survey collection in Edinburgh, have proved to be monograptid or dimorphograptid stipes. No Ordovician rocks are recorded on Survey maps or in memoirs from the original locality in Dumfriesshire, and Lapworth in 1878 (p. 331) only recorded it with a query. No specimens are known to the author approaching the length assigned by Hopkinson to *C. gracilis* ($\frac{5}{8}$ in. to $\frac{3}{4}$ in., about 16–19 mm.), except var. *maximus* Ruedemann, nor are there references to such in literature other than Hopkinson. Specimens identified as this species by later writers can in all cases be accommodated in *C. calicularis*.

The American species have been listed and described recently by Ruedemann (1947). The following tentative suggestions are made regarding synonymy :—

C. calicularis var. *americana* Ruedemann is probably synonymous with *C. curtus* Lapw., the species to which he referred it in 1908.

C. curtus mut. *pristinus* Ruedemann is probably synonymous with *C. incurvus* Hadding.

C. comma Ruedemann is clearly a valid species, distinctly shorter, broader, and more curved than the typical *C. curtus*.

C. gracilis and its mutation *perungulatus* Ruedemann = *C. calicularis* Nich.

C. gracilis var. *maximus* Ruedemann is represented by a single specimen only, figured natural size, and remains doubtful, for it seems possible that two rhabdosomes are here superposed.

C. tricornis Ruedemann is peculiar in having apparently spines instead of broad processes on the sicula and thecae, and would thus be a valid species.

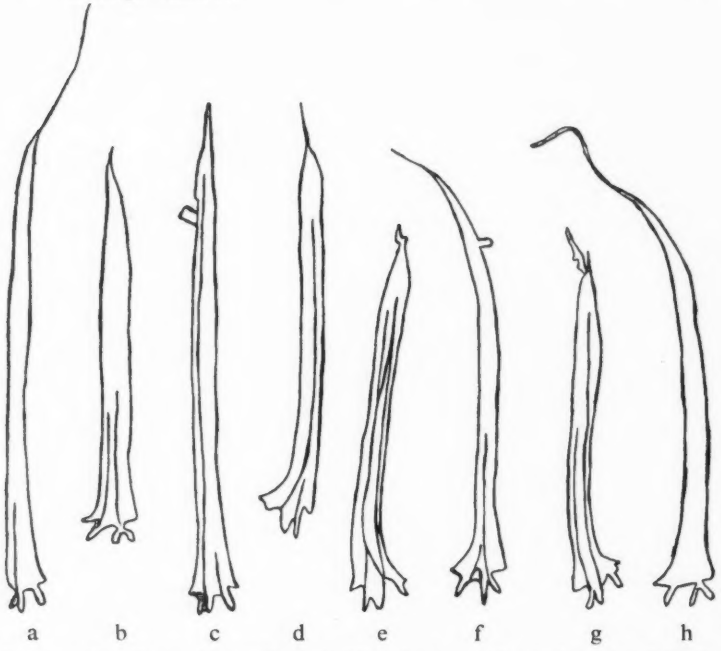
C. ultimus Ruedemann appears to be very close to *C. incurvus* in size and with similar rather broad apertural processes; its late presence in North America cannot, unfortunately, be correlated as yet with European zones.

Fuller synonymies of all species appear in Ruedemann (1947), but many of the references are to faunal lists only, which, in view of the past difficulties, invite further investigation before they can be accepted.

Corynoides calicularis Nicholson

Text-figure 1

1867 *Corynoides calicularis* Nicholson, p. 108, pl. vii, figs. 9–11.
1876 *Corynoides calicularis* Lapworth, pl. iv, fig. 91.
1877 *Corynoides calycularis* Lapworth, pl. vii, fig. 18.
1908 *Corynoides gracilis* Ruedemann, p. 237, pl. 13, figs. 2, 12, 15, 16, text-figs. 133–5.
1908 *Corynoides gracilis* mut. *perungulatus* Ruedemann, p. 239, pl. 13, figs. 3, 9–11, 13, 14, text-figs. 136–139.
1944 *Corynoides* cf. *calicularis* Bulman, p. 27, pl. ii, fig. 12, text-fig. 13.
1947 *Corynoides* cf. *gracilis* Bulman, p. 72, text-figs. 39, 40.
1947 *Corynoides gracilis* Ruedemann, p. 361, pl. 58, figs. 34–37a.
1947 *Corynoides gracilis* mut. *perungulatus* Ruedemann, p. 361, pl. 58, figs. 38–46.
non 1908 *Corynoides calicularis* Ruedemann, p. 234, pl. 13, figs. 1, 6–8, text-figs. 126–131.



TEXT-FIG. 1.—*Corynoides calicularis* Nicholson. × 5. a, b, f, h—P 1933 ; c—H 4107 ; d, e—H 4113 ; g—H 4115. All in the Nicholson Collection, British Museum (Nat. Hist.).

Rhabdosome 9–13 mm. long, with an average breadth of 0·6 mm., widening distally to about 1·4 mm., generally slightly curved.

Horizon : Glenkiln-Lower Hartfell Shales ; Normanskill and Lower Canajoharie Shales.

Lectotype : P 1933, Nicholson Collection, British Museum (Nat. Hist.).

The specimen is labelled in Nicholson's handwriting and is undoubtedly a syntype. Of the individuals on the piece of shale, that shown here as Text-fig. 1*f* is selected as the type.

The rhabdosome consists of a sicula and two thecae, straight or slightly curved throughout their length, with more pronounced curvature at the distal end. The curving appears to be always in the same direction so that the first theca is on the convex side of the sicula. A third theca is frequently developed in this species as a short, free tube.

Nicholson's figures are to be regarded as diagrammatic and cannot be matched with his description or with any of the material in his collection, but Lapworth's figure seems to be a fairly accurate representation of the common form of the species. In spite of considerable variation in length (which is allowed in the original diagnosis) and a rather distinct grouping into two lengths, most of the specimens on a piece of shale being either 8–9 mm. or 11–13 mm. long, the species appears to be a fairly well-defined unit.

As Bulman has recently mentioned (1947, p. 76), Ruedemann's mutation *perungulatus* represents an immature state and both the American forms given above agree well with what is here accepted as *C. calicularis* of Britain.

C. calicularis occurs abundantly at certain horizons in the Moffat Shales, well preserved specimens being especially common in the zone of *Climacograptus wilsoni* (in relief), and in association with *C. caudatus* in the zone of *Dicranograptus clingani*. It is also found in the *Dicranograptus* Shales of South Wales and the Middle Dicellograptus Shales of Jemtland, Sweden.

Corynoides curtus Lapworth

Text-figure 2

1876 *Corynoides curtus* Lapworth, pl. iv, fig. 92.
1877 *Corynoides curtus* Lapworth, pl. vii, fig. 19.
1915 *Corynoides curtus* Hadding, p. 26, pl. iii, figs. 28, 29.
1944 *Corynoides curtus* Bulman, p. 24, pl. ii, figs. 9–11, text-figs. 11, 12.
? 1908 *Corynoides curtus* Ruedemann, p. 240, pl. 13, figs. 4, 17–21.
? 1947 *Corynoides calicularis* var. *americana* Ruedemann = *C. curtus* Ruedemann 1908 (above).

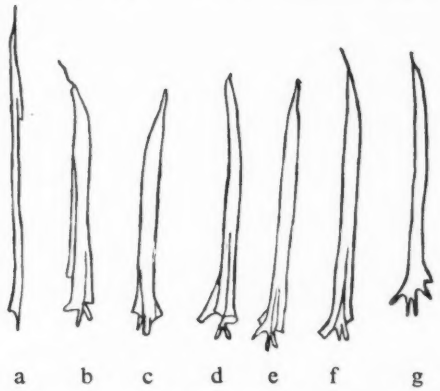
Rhabdosome 6–8 mm. long and 0·4 mm. in average breadth, widening at the distal end to 1 mm. ; generally almost straight.

Recorded by Lapworth and Hadding from the zone of *Dicranograptus clingani* only, but probably occurs at lower horizons as well.

Lectotype : in the Lapworth Collection, Birmingham ; the specimen here figured as Text-fig. 2*d*. This species was never described by Lapworth, and as his figures are natural size there has been some difficulty in determining its characters. Only two pieces of shale labelled as bearing *C. curtus* have come to light as yet, one of which fortunately is in Lapworth's writing and can be regarded as a syntype.

The adult rhabdosome consists of a sicula and two thecae, no trace of a third theca having yet been observed. The details of the thecae cannot be made out from specimens in shale as the preservation is too poor and the individuals are crowded on one another, but the form is very similar to that of the other species.

This species does not appear to be at all common, judging from the



TEXT-FIG. 2.—*Corynoides curtus* Lapworth. × 5. a, e, f, g—10638, Geol. Surv., London; b—8139, Nicholson Collection, Geol. Dept., Aberdeen University; c, d—Lapworth Collection, Geol. Dept., Birmingham University.

few specimens which have been found. Those from the Moffat Shales are unfortunately not zonally fixed and appear to be restricted to a few bands where, however, they swarm over the whole surface to the exclusion of all other forms. The horizon of the specimens described by Bulman is not definitely fixed by the associated fauna but is considerably lower than *Dicranograptus clingani*.

The American form is, as was noted by Hadding (1915, p. 26), distinctly more curved than the European ones and is found in beds of Lower Trenton age.

Corynoides incurvus Hadding

Text-figure 3

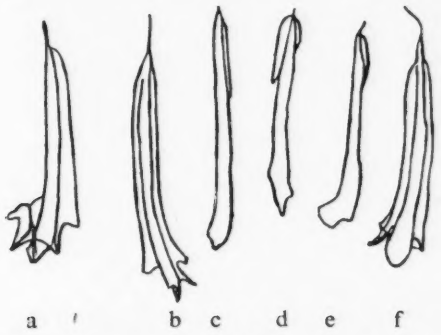
1915 *Corynoides incurvus* Hadding, p. 25, pl. iii, figs. 24–7.
? 1908 *Corynoides calicularis* Ruedemann, p. 234, pl. 13, figs. 1, 6–8, text-figs. 126–131.
? 1947 *Corynoides curtus* mut. *pristinus* Ruedemann = *C. calicularis* Ruedemann 1908 (above).

Rhabdosome 5–7 mm. long and 0·8 mm. broad, slightly curved throughout its length and more abruptly at the distal end, where it widens to 1·5 mm.

Hadding records it from the zone of *Dicranograptus clingani* in Bornholm, and it has now been found in the same zone at Dobb's Linn, Moffat.

Lectotype : Specimen figured by Hadding, 1915, pl. iii, fig. 24; Geological-Mineralogical Institute, Lund.

This species is most easily recognized by its comparatively great



TEXT-FIG. 3.—*Corynoides incurvus* Hadding. × 5. a—8161 ; b, c—8157 ; d, e, f—8156, all in Nicholson Collection, Geol. Dept., Aberdeen University.

breadth. Slightly immature specimens show a thecal arrangement similar to that in the rest of the genus, but the apertural processes appear to be much broader and the distal end in adults is generally distorted by twisting in compression. The proximal end frequently shows the first and second thecae arising at slightly different levels, and the second theca must cross to its own side of the sicula very early in its development.

The American form referred to above is very close to the European ones, so far as can be judged from the published figures and descriptions, and they are probably specifically identical.

Corynoides serpens nov. sp.

Text-figure 4

1899 *Corynoides* nov. sp., Peach and Horne, p. 238

Rhabdosome about 10 mm. long, average breadth 0·5 mm., widening distally to about 1·5 mm. ; strongly curved, semi-circular or S-shaped.

Horizon : Lower Hartfell Shales.

Type : R 5334, Geological Survey of Scotland, Edinburgh (fig. 4*b*).

This species is very close to *C. calicularis* in size and general character, but is easily distinguished by the pronounced curvature shown by all specimens. The associated fauna shows no abnormalities and the curvature can hardly be regarded as an environmental pathological

condition. No other species of *Corynoides* has been found along with it.

All the specimens, which are crowded on several pieces of shale, come from the railway cutting opposite Kirkton, near Abington, Lanarkshire, and are associated with *Orthograptus* cf. *intermedius*, *Lasiograptus* cf. *harknessi*, *Climacograptus* cf. *scharenbergi*, *C.* cf. *miserabilis*, indicating a Lower Hartfell age.

TEXT-FIG. 4.—*Corynoides serpens* nov. sp. × 5. a—R 2148 ; b, c—R 5334, all in the Geol. Surv., Edinburgh.

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New Lower Ordovician Brachiopods from the Llandeilo-Llangadock District

PART I

(PLATE VIII)

By ALWYN WILLIAMS

ABSTRACT

The following systematic account of new Lower Ordovician Brachiopods has been divided into two sections. Part I includes descriptions of a new species and variety of *Resserella*, two new Dalmanellas, and two new Horderleyellas, and some notes on the value of B. B. Bancroft's methods of separating Dalmanellid species and genera. In Part II two new species and a new variety of *Hesperorthis*, *Rostricellula*, and *Sowerbyella* respectively are recorded; an investigation of *Orthis turgida* McCoy shows that forms referred to this species belong either to *Corineorthis*, two new species of which are described, or *Paurorthis*.

INTRODUCTION

THE Lower Ordovician rocks of the Llandeilo–Llangadock area have yielded a rich shelly fauna hitherto largely undescribed. The following systematic account of these new fossils is divided into two parts. Part I is concerned exclusively with Upper Llanvirn-Llandeilo Dalmanellids, in the investigation of which the techniques implemented by B. B. Bancroft in his study of Caradocian forms have been applied. The conclusions as to the efficacy of his ribbing notation are set out as an introduction to this section.

In Part II the remaining brachiopods are described. An investigation of *Orthis turgida* McCoy, two syntypes of which came from this district, has led to the belief that the types include three species belonging to two different genera. In an attempt to unravel the relationships existing between these species it has been necessary to include a description of a Caradocian form from North Wales (*Corineorthis globosa* sp. nov.), which has not been found in the area surveyed.

ACKNOWLEDGMENTS

I wish to express my indebtedness to the late Professor H. P. Lewis of Aberystwyth, for his meticulous supervision and constant encouragement throughout this investigation. My thanks go, too, to Dr. C. J. Stubblefield, who gave me considerable advice in the earlier stages of the work and allowed me access to relevant material in the Survey Museum, and who later read the manuscript and made very many valuable comments thereon; to Professor O. T. Jones, for helpful discussions on the various aspects of faunal distribution; to Mr. J. C. Challinor, for suggestions in the early stages of the work; and to Mr. A. G. Brighton, for allowing me access to specimens in the Sedgwick Museum.

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The Ordovician Dalmanellids

The genotype of *Dalmanella* has long been the subject of considerable controversy, and although there is now general agreement on the status and limits of the genus, it is felt that a brief synopsis of the situation is desirable before entering into a discussion on the Lower Ordovician Dalmanellids.

When Hall and Clarke (1892, p. 205) established the genus *Dalmanella* they named *Orthis testudinaria* Dalman as type. Their generic description, however, was based upon a series of North American shells (= *D. rogata* Sardeson) which subsequently proved to be entirely different. (Schuchert and Cooper, pp. 120–1, who also point out that Meek, Sardeson, and Raymond had all expressed opinions to this effect.)

In 1928 Bancroft erected three genera, namely *Resserella* (genotype *Orthis canalis* Sow.), *Onniella* (genotype *O. brøggeri* Bancroft), and *Wattsella* (genotype *W. wattsi* Bancroft); *D. rogata* proved to be an Onniellid and *O. testudinaria* a Wattsellid (Schuchert and Cooper 1932, p. 120).

In 1932 (p. 119 et seq.) Schuchert and Cooper took as genotype for their emended description of *Dalmanella* not *O. testudinaria* which Hall and Clarke had named but *D. rogata*, which they had actually used. Accordingly, Schuchert and Cooper placed *Onniella* in synonymy with *Dalmanella* and *O. testudinaria* became *Wattsella testudinaria*. In this monograph *Resserella* was accepted provisionally as a distinct genus, but some misgivings as to the validity of its segregation from *Onniella* were expressed.

Öpik, however, maintained (1933, pp. 14–16) that *O. testudinaria* must remain the type of *Dalmanella* since Hall and Clarke had named this species as genotype even if it involved modifying the concept of *Dalmanella*. He therefore considered *Wattsella* a synonym of *Dalmanella* and revived *Onniella* for the *D. rogata* type of shell.

Cooper (1942) accepted Öpik's contention. By this time, too, he had come to the conclusion that *Onniella* and *Resserella* were not generically separable and placed the former in synonymy with the earlier founded *Resserella*.

Bancroft (1945, p. 210) refused to recognize *Dalmanella* on the grounds that it was being used in conflicting senses, and in addition to retaining *Resserella*, *Onniella*, and *Wattsella*, erected two new genera, *Soudleyella* and *Raymondella* (preoccupied = *Bancroftina*), and one new subgenus of *Resserella—Howellites*.

The differences he cites in the descriptions of these new genera are of great import for detailed zonal work in the Caradocian, but there is no internal change displayed in these Dalmanellids fundamental enough to be at present acceptable as the basis of generic distinction. In this belief the writer provisionally refers all the Caradocian Dalmanellids to the two genera recognized by Cooper (1942), *Dalmanella* and *Resserella* (s.l.), interpreting the latter to include *Resserella* s.s. *Resserella* (*Howellites*), *Soudleyella*, and *Bancroftina*, as well as *Onniella*.

A Note on the Bancroft Notation for the Ribbing System in Orthids (*sensu lato*)

In 1928 [1] Bancroft described a method of enumerating Dalmanellid ribbing systems, and claimed that the notation revealed a series of constant ribbing patterns which have a generic and specific significance. His descriptions of Caradocian Dalmanellids (*sensu lato*), published posthumously in 1945 indicate that he used the notation extensively in definitions of genera and species and the results seemed to confirm his early claims.

The notation was accordingly applied to new species of Dalmanellas Horderleyellas and Resserellas, of Llanvirn-Llandeilo age, collected from the Llandeilo area, and special regard was given to the problems (*a*) why the ribbing split into certain standard patterns, and (*b*) what were the relationships between this older fauna and the Caradocian derivatives.

The answer to the first point seems to be that the tendency to variation in rib patterns is related to the contour of the shell, and is immediately apparent when the notation is applied to the ventral valve as well as the dorsal one (Bancroft used the notation for dorsal ribbing only). The insertion of a rib depends upon the actual slope, and it has been found that branches split off, in the majority of cases, down slope.

[1] The notation can be summarized briefly as follows : Ribs originating at the umbo are termed primaries and are numbered 1, 2, 3, 4, etc., primary 1 being nearest the median line, and primary 4 furthest away. Secondary ribs which split off from the primaries are lettered a, b, c, etc., a being the earliest to split off, b the next, and so on. Tertiary ribs which split off from the secondaries are numbered 1, 2, 3, etc., 1 being the earliest to arise, and so on ; and for ribs of higher orders the numerals continue to alternate with the letters. Thus, 2a1 denotes the earliest tertiary (1), on the earliest secondary (a), on the second primary (2).

Whether the rib splits off on the inside (i.e. towards the median line) or on the outside (i.e. away from the median line) of the parent rib is also very important, and Bancroft used the symbol $^-$ to indicate the inner ribs, and the symbol $^\circ$ to denote the outer ribs. It must be emphasized that the terms " inner " and " outer " sides are always in reference to the *immediate parent* of the rib in question. Thus 2a°, which is the first secondary to arise on the outer side of primary 2, can bear a tertiary between it and the primary and which, lying on the inner side of its parent, is denoted 2a°1$^-$.

For example in dorsal valves with a sinus, primary (1) branches on the inside (i.e. towards the sinus axis). $1\bar{a}$, $1\bar{a}1^{-}$, $1\bar{b}$, 1. In ventral valves with a sharply convex outline, primary (1) is characterized by external branching on either side, e.g. :—

$$1^{\circ}1a^{\circ}, 1a^{\circ}, 1b^{\circ}, 1, 1b^{\circ}, 1a^{\circ}, 1a^{\circ}1^{\circ}.$$

The operation of such a factor is well exemplified by the ribbing system in genera like *Corineorthis* Stubblefield, where the extreme change in contour in both valves (the dorsal valve has a strong sinus, but is markedly convex, the ventral valve is gently convex medianly and concave laterally) is accompanied by a corresponding change of branching from internal to external in the dorsal valve, and from external to internal in the ventral valve.[1]

A comparison of Upper Llanvirn Dalmanellids with those of Caradocian age shows that there is also a tendency to reduce the number of primaries in more specialized forms which therefore results in a complex secondary, tertiary, and quaternary branching. Forms from the Lower Ordovician have up to 28 primary ribs on a valve (approaching the number in the Orthid protostocks) whereas Upper Ordovician forms described by Bancroft generally have about 14 to 16 primary ribs. Throughout the Ordovician the stocks retained a remarkably uniform outline, so that the reduction in the number of primaries resulted in a more discrete branching system. In other words, primary sectors of Llanvirn and Lower Llandeilo Dalmanellids are always smaller than they are in Caradocian species.

In view of these facts the Bancroft notation is valuable in assessing the stage of development of a Dalmanellid, and in generic discrimination especially when only fragments of external casts are found. This last qualification should be borne in mind because, when abundant material is available, other characters will provide equally good data more easily appreciated. The differences between entire external casts of e.g. *Horderleyella* and *Dalmanella* can be estimated in a glance and need no tedious " counts " to confirm them. In the case of the stage of development, too, the nature of the internal parts tells the story far more quickly and as accurately as notational work.

As far as specific differentiation, based upon notational systems, is concerned, Bancroft seems to have demonstrated that they have a

[1] In Table VIII, columns 1 and 2 (Bancroft, 1945, p. 216), one would expect that since $1\bar{b})1a^{\circ}$ and $2\bar{a}1^{-})2\bar{b})^{-}$ in the respective ratios 93 and 85 (*Resserella* (s.l.) *inconstans*) to 55·7 and 21·3 (*Resserella* (s.l.) *reushi*) that the former has sharply raised " shoulders " on either side of a narrow mesial sinus and the latter a weakly convex dorsal valve. This is so, and it is the sharp accentuation of " shoulders " in *Harknessella* that contributes in the main to production of ribbing patterns distinct from *Dalmanella* and *Resserella*.

distinct merit, and has used the number and disposition of ribs at the shell periphery, and the early or late insertion of various secondaries, etc., in relation to others for specific distinction. The practice is, however, open to a certain amount of qualification.

The number of ribs present at the shell periphery need indicate nothing more than that the specimen is larger or smaller than another. In the following descriptions it will be seen that *Horderleyella convexa* sp. nov. has a more complex ribbing system than *Horderleyella lata* sp. nov., but it is due to the fact that *H. convexa* is much larger than *H. lata*. A similar relationship exists between *Dalmanella prototypa* sp. nov. and *Dalmanella parva* sp. nov.[1]

The early or late insertion of a rib relative to another, as stated earlier, seems to be related to the contour of a shell. In the case of noticeably distinct shells the eye can appreciate what notational counts confirm, that, for example, the dorsal valve of one species is much flatter than that of another. But, by use of notational studies, it is possible to draw distinctions so subtle that unless they are substantiated by other differentiating characters they may represent variations within an inter-breeding community. Bancroft worked on many hundreds of well-preserved casts to arrive at the norms for each of his species, and there is little doubt that owing to individual variation, especially in so delicate a criterion as the insertion of a tertiary rib, it is necessary to work with large numbers to reach any reasonable conclusion on specific relationships.

Dalmanellacea Schuchert and Cooper 1931

DALMANELLIDAE Schuchert 1929, emended Schuchert and Cooper 1932, emended Bancroft 1945

Resserella Bancroft 1928, emended Cooper 1942

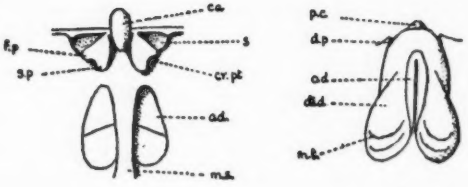
Resserella immatura sp. nov.

Pl VIII, figs. 1–4, Text-fig. 1

Dimensions.—

Syntypes.			*Length.* *cm.*	*Breadth.* *cm.*
(1)	Internal mould, dorsal valve	G.S.M. 75,233	1·1	1·3
(2)	External cast, dorsal valve	G.S.M. 75,234	1·2	1·4
(3)	Internal mould, ventral valve	G.S.M. 75,235	1·4	1·4
(4)	External casts, ventral valves	G.S.M. 75,236	Incomplete	

[1] If future work is carried out along these lines it would probably be expedient to accept a standard length of radius from the umbo (e.g. 1·5 cm.), at which to make notational readings. This will have the advantage of ensuring comparisons at approximately the same stage in the development of individuals. Compare, for instance, the considerable differences between readings at the shell periphery, and at a length of 1 cm. from the umbo, in the gerontic syntype of *Dalmanella prototypa* sp. nov. (pp. 168–9).



a *b*

TEXT-FIG. 1 (*a*).—Cardinalia of *Resserella immatura* (syntype 1) × 3. ad., adductor scar ; ca., cardinal process ; cr.pt., crural pit ; fp., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Resserella immatura* sp. nov. (syntype 3) × 3. ad., adductor scar ; did., diductor scar ; d.p., dental plates ; m.t., muscle track ; p.c., pedicle callist.

External characters.—Shape : transverse, sub-rectangular with occasional specimens rather longer. Hinge-line straight, wide, with the greatest width of the shell anterior to the hinge-line. Moderately bi-convex, the ventral valve more so, the dorsal valve having an ill-defined mesial sinus. Delthyrium open, inter-areas small, notothyrium open but generally filled by the cardinal process.

Ribbing.—Multicostellate, very fine. Only a small number of well-preserved, entire, external casts have been collected, but syntype 2 seems to be representative,

$1\bar{a}$, $1\bar{a}1$, 1, 1a°.
$2\bar{a}1$, $2\bar{a}$, $2\bar{b}$, $2\bar{c}$, 2.
$3\bar{a}1\bar{a}$, $3\bar{a}1$, $3\bar{a}\bar{2}$, $3\bar{a}$, $3\bar{b}1$, $3\bar{b}$, $3\bar{b}1°$, $3\bar{c}1$, $3\bar{c}$, $3\bar{d}$, 3, 3b°, 3a°, 3a1°.
$4\bar{a}\bar{2}\bar{a}$, $4\bar{a}\bar{2}$, $4\bar{a}1$, $4\bar{a}$, $4\bar{a}1°$, $4\bar{b}1$, $4\bar{b}$, $4\bar{b}1°$, $4\bar{c}$, 4, 4a° (strong).
$5\bar{a}1$, $5\bar{a}$, $5\bar{b}$, 5, 5a°, etc.

the size of sector III is distinctive, it is larger than sector I and II. (In the Caradocian material described by Bancroft the reverse is true.) Shell further ornamented by well-marked concentric growth lines, and by small exopunctae (?) arranged longitudinally between the ribs.

Dorsal interior.—Notothyrial platform small, supporting a cardinal process consisting of a fused myophore and shaft, and bounded laterally by a pair of weak and very small, slightly diverging crural processes each of which has a small crural pit, so that even in mature forms there is no complete fusion of fulcral and supporting plates. Teeth sockets, sharp. The notothyrial platform is continued anteriorly for about half the length of the shell as a mesial ridge. Adductor scars somewhat obscure, subequal ; in one gerontic specimen the anterior pair give off to the front a pair of pallial sinuses. Ribbing is apparently confined to the periphery, but in very well preserved specimens is continued very faintly to the muscle scars.

Ventral interior.—Delthyrium moderately deep, hinge-line bearing a pair of teeth bounded laterally by crural fossettes and supported by a pair of dental lamellae which are continued anteriorly as boundaries to the musculature. Delthyrial apex partially closed by a small but conspicuous, triangular, apical plate (pedicle callist). Muscle scar well defined. Adductors lanceolate, separated by a median ridge. Diductors sub-flabellate, elongate, extending anteriorly to enclose the adductors. Ribbing marked on the periphery, and continued very faintly over most of the interior.

Type horizon.—Middle Llandeilian.

Type locality.—Quarry. 550 yards E. of Glan Towy Farm, 3 miles N.E. of Llandeilo.

Resserella immatura var. *plana* var. nov.

Pl. VIII, figs. 5 and 6

Syntypes.		*Length.* cm.	*Breadth.* cm.
(1) Internal mould of dorsal valve	G.S.M. 75,237	1·7	2·1
(2) External casts of both valves	G.S.M. 75,238	incomplete	
(3) Internal mould of ventral valve	G.S.M. 75,239	1·8 (est.)	2·0

The new variety agrees in all respects of internal structure to *R. immatura*; the persistent varietal differences are the much larger size and the very feeble convexity of both valves. The new variety occupies a definite horizon comprising the lower beds of the Lower Llandeilo.

Type localities.—Small quarry 100 yards N.E. of Pant-y-ffynon Farm, 1½ miles E. of Llandeilo, and old quarry 350 yards E. of Old Dynevor Castle, Llandeilo.

Discussion.—The Llandeilian Resserellas investigated form a more primitive group than the Caradocian material. Four factors render them specifically separable from their derivatives.

(1) *Immaturity of the crural processes*

In Llandeilo forms the crural processes are very small and slender, and even in gerontic individuals show crural pits. The effect is that in moulds the socket line is only moderately or slightly divergent and the pre-socket line slightly sinuated by the crural pit is oblique to the median line.

(2) Obscurity of the dorsal muscle scars.

(3) Pronounced ventral muscle scars.

(4) Well marked pedicle callist. (The pedicle callist appears to be present in some, if not all, Caradocian types but has not been mentioned in descriptions. It is less conspicuous than in *R. immatura*.)

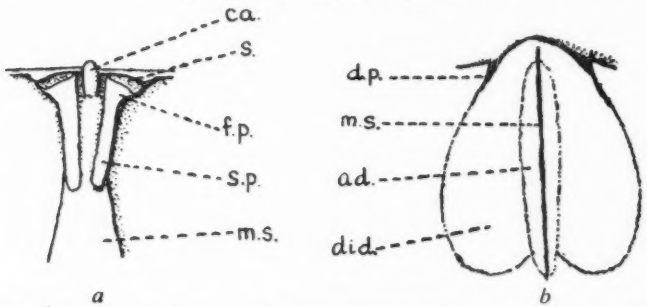
Dalmanella Hall and Clarke 1892, emended Cooper 1942

Dalmanella prototypa sp. nov.

Pl. VIII, figs. 7–10, Text-fig. 2

Dimensions.—

Syntypes.			*Length.* cm.	*Breadth.* cm.
(1)	Internal mould of dorsal valve	G.S.M. 75,248a	0·9	1·1
(2)	External cast, complement Syntype (1)	G.S.M. 75,248b	0·9	1·1
(3)	External cast of dorsal valve	G.S.M. 75,249	0·95	1·2 (est.)
(4)	Internal mould of ventral valve	G.S.M. 75,250a	1·4	1·7
(5)	External cast, complement Syntype (4)	G.S.M. 75,250b	1·4	1·7



TEXT-FIG. 2 (*a*).—Cardinalia of *Dalmanella prototypa* sp. nov. (syntype 1) × 6. ca., cardinal process ; f.p., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Dalmanella prototypa* sp. nov. (syntype 4) × 6. ad., adductor scar ; did., diductor scar ; d.p., dental plates ; m.s., median septum.

External characters.—Shape : sub-circular, typically Orthoid, with the greatest width anterior to the straight hinge-line, subequally bi-convex, the dorsal valve almost plane with a well marked sinus, the ventral valve gently convex.

Rib pattern.—Multicostellate. Primitive, the basic element being : primary, secondary (*a*), secondary (*b*), tertiary. This, together with the large number of primaries (up to 14 +) distinguishes it immediately from later Dalmanellids (s.s.).

Dorsal Valve.	*Ventral Valve* (gerontic individual).
	1 ?
1$\bar{a}$1, 1$\bar{a}$, 1$\bar{b}$, 1.	2$\bar{a}$, 2, 2c°, 2b°, 2b1°, 2a°, 2a1°, 2a2°, 2a2a°, 2a2a1°.
2$\bar{a}$1, 2$\bar{a}$, 2$\bar{b}$, 2, 2a°.	3$\bar{a}$, 3, 3c°, 3b°, 3b1°, 3a°, 3a1°, 3a2°, 3a2a°.
3$\bar{a}$1, 3$\bar{a}$, 3$\bar{b}$, 3.	4$\bar{a}$, 4, 4c°, 4b°, 4b1°, 4a°, 4a1°, 4a2°, 4a2a°.
4$\bar{a}$1, 4$\bar{a}$, 4$\bar{b}$, 4, 4a°.	5$\bar{a}$, 5, 5c°, 5b°, 5b1°, 5a°, 5a1°, 5a2°, 5a2a°.
5$\bar{a}$1, 5$\bar{a}$, 5$\bar{b}$, 5.	6$\bar{a}$, 6, 6c°, 6b°, 6b1°, 6a°, 6a1°, 6a2°, 6a2a°.
6$\bar{a}$1, 6$\bar{a}$, 6$\bar{b}$, 6.	7$\bar{a}$, 7$\bar{a}$1°, 7, 7c°, 7b°, 7b1°, 7°a$\bar{1}$, 7a°, 7a1°, 7a2°, 7a2a°.
etc.	8$\bar{a}$, 8$\bar{a}$1°, 8, 8c°, 8b°, 8b1°, 8a°, 8a1°, 8a2°, 8a2a°.
	9$\bar{a}$, 9, 9c°, 9b°, 9b1°, 9a°$\bar{1}$, 9a°, 9a1°, 9a2°, 9a2a°.
	8 more ribs.

Pattern for the above ventral valve at standard length of 1 cm.
2, 2b°, 2a°, 2a1°, 2a1a°.
3, 3b°, 3a°, 3a1°.
4, 4b°, 4a°, 4a1°.
5$\bar{a}$, 5, 5b°, 5a°, 5a1°.
6, 6b°, 6a°, 6a1°.
7$\bar{a}$, 7 7b°, 7a°, 7a1°.
etc.

Dorsal interior.—Notothyrial platform, oval, small, extending as a median ridge anteriorly and supporting a small cardinalia consisting of a cardinal process, and a pair of crural processes. Cardinal process, moderately slender, simple. Teeth sockets not deeply notched. Each crural process consists of an extremely abbreviated fulcral plate and a longer supporting plate (the latter plates form small parallel notches in moulds). Muscle scars obscure. Ribbing deeply impressed in internal moulds of both valves.

Ventral valve.—Umbonal region moderately deep, delthyrium open, dental plates short, well marked, diverging anteriorly. Diductor muscular scars obscure.

In syntype 4, a gerontic individual, the muscle scar is faintly seen to consist of a pair of sub-triangular diductor scars separated by a slender lanceolate adductor scar which extends anteriorly beyond the limit of the diductors.

Type horizon.—Lower *D. bifidus* shales.

Type locality.—Band 40 feet below the Upper Llanvirn Grit, 240 yards W. of Llwyn Bedw Farm, 2 miles E.S.E. of Llandeilo.

Dalmanella parva sp. nov.

Pl. VIII, figs. 11–14.

Dimensions.—

Syntypes.			*Length.* cm.	*Breadth.* cm.
(1)	Internal mould of dorsal valve	G.S.M. 75,251	0·45	0·55
(2)	„ „ ventral valve	G.S.M. 75,252	0·5	0·6
(3)	External cast of dorsal valve	G.S.M. 75,253	0·4	0·5
(4)	„ „ ventral valve	G.S.M. 75,254	0·4	0·5

External characters.—Shape ; sub-circular, typically Orthoid, with greatest width anterior to a straight hinge-line. Dorsal valve gently convex, especially posteriorly, where the shell is raised with two shoulders, one on either side of a distinct mesial sinus. Ventral valve, sharply convex mesially, umbonal region moderately pronounced.

Ornamentation consists of concentric growth lines, and a multicostellate primitive ribbing system on the pattern, primary, secondary (*a*), secondary (*b*), tertiary.

Dorsal Valve.	*Ventral Valve.*
1$\bar{a}$, 1.	1a°, 1, 1a°.
2$\bar{a}$1, 2$\bar{a}$, 2$\bar{b}$, 2.	2, 2b°, 2a°, 2a1°.
3$\bar{a}$1, 3$\bar{a}$, 3$\bar{b}$, 3.	3, 3a°.
4$\bar{a}$, 4.	4, 4b°, 4a°, 4a1°.
5$\bar{a}$1, 5$\bar{a}$, 5.	5$\bar{a}$, 5, 5a°.
6$\bar{a}$, 6, 6a.	6$\bar{a}$, 6, 6a°.
7$\bar{a}$, 7.	4 more ribs.
8.	6a°) 6$\bar{a}$.
9.	5a°) 5$\bar{a}$.

Dorsal interior.—Notothyrial platform sub-parallel, extending anteriorly to form a mesial ridge and supporting a styliform cardinal process and a pair of crural processes. The latter consist of a pair of very abbreviated widely divergent fulcral plates, and a pair of sub-parallel, larger supporting plates. Dental sockets strongly diverging anteriorly, well defined. Adductor impressions generally not evident except faintly in gerontic individuals as a pair of oval bodies. Ribbing deeply impressed on internal moulds of both valves.

Ventral interior.—Umbonal region deep, with dental lamellae well marked, diverging moderately anteriorly. Diductor scars generally obscure, but occasional specimens bear a faint subcordate outline not enclosing the adductors.

Type horizon.—Basal beds of the Lower Llandeilo.

Type locality.—Quarry 300 yards W. of Ysgubor Wen Farm, 1¼ miles E. of Llandeilo.

Discussion.—The new sp. is clearly related to *D. prototypa* but is much smaller, more convex, and the component parts of the cardinalia better developed than in the latter species.

The discovery of these primitive Dalmanellas in strata of Llanvirn age rather complicates the concepts [1] of generic origin within the Dalmanellidae and the relationship that this family bears to the Heterorthidae.[2]

For although the species under discussion are the oldest Dalmanellids (*sensu lato*) found in the Llandeilo area, specimens of *Horderleyella convexa* sp. nov., with highly developed cardinalia and muscle scars, have been collected from strata 100 feet higher than the horizon of *Dalmanella prototypa* sp. nov., and perfectly distinct Resserellas occur at the top of the Llanvirn, along with *Dalmanella parva* sp. nov. It seems unlikely therefore that the *Resserella* or the *Horderleyella* stocks

[1] Bancroft (1945, p. 189) : " *Wattsella* (synonym of *Dalmanella*) in which the fulcral plates normally persist to maturity may be regarded as the parent genus of the others " (including *Horderleyella*).

[2] These two families are discussed here in the sense they are used by Bancroft and not as understood by Schuchert and Cooper. The former (1945, pp. 187–9) has advanced valid reasons for the removal of *Horderleyella* from this family, as reconstituted, to the Heterorthidae.

diverged directly from the Dalmanellas, as was previously believed, if they had they would show *initially* the same immaturity of internal structures.

HETERORTHIDAE Schuchert and Cooper 1931, emended Bancroft 1945

Harknessellinae Bancroft

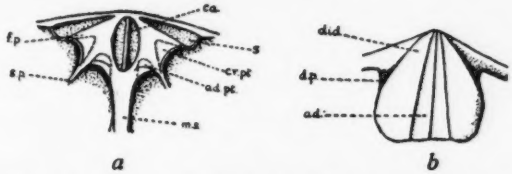
Horderleyella Bancroft

Horderleyella convexa sp. nov.

Pl. VIII, figs. 15–17, Text-fig. 3

Dimensions.—

Syntypes.			*Length. cm.*	*Breadth. cm.*
(1)	Internal mould of dorsal valve	G.S.M. 75,240	1·1	1·6 (est.)
(2)	,, ,, ventral valve	G.S.M. 75,241	1·5 (est.)	2·0 (est.)
(3)	External cast of dorsal valve	G.S.M. 75,242	incomplete	
(4)	Internal moulds of ventral and dorsal valves	G.S.M. 75,243	incomplete	
(5)	Internal mould of dorsal valve	G.S.M. 75,244	incomplete	



TEXT-FIG. 3 (*a*).—Cardinalia of *Horderleyella convexa* sp. nov. (syntype 1). × 3. ad.pt., adductor pit ; ca., cardinal process ; cr.pt., crural pit ; f.p., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Horderleyella convexa* sp. nov. (syntype 2). ad., adductor scar ; did., diductor scar ; d.p., dental plate.

External characters.—Shape : weakly Harknesselloid, with greatest length at hinge-line which is feebly mucronate. Sub-equally bi-convex, the ventral valve more so than the dorsal valve. Dorsal valve with a well-marked median sinus, the ventral valve slightly carinate mesially.

Ribbing, multicostellate, primitive in arrangement, e.g. syntype 3.

$1\bar{a}$, 1.
$2a\bar{1}$, $2\bar{a}$, $2\bar{b}$, 2, 2a°.
$3a\bar{1}$, $3\bar{a}$, $3\bar{b}$, 3, 3b°, 3a°.
$4a\bar{1}$, $4\bar{a}$, 4, 4b°, 4a°.
$5\bar{a}$, $5\bar{b}$, 5, 5b°, 5a°.
etc.

Dorsal interior.—Notothyrial platform, square, rather elevated, passing anteriorly into a median septum, and supporting, posteriorly,

a simple, fairly stout, cardinal process and a pair of crural processes. Each process consists of an inner supporting plate and an outer fulcral plate, both fairly massive and separated by a long narrow crural pit. Dental sockets are sharp, diverging anteriorly. A pair of deep adductor pits, one on either side of the median septum, are each bounded laterally by a scarcely elevated partition which in all probability form diverging anterior extensions of the supporting plates.

The adductor muscle scars are not well defined anteriorly, but consist of a pair of elongated oval bodies. In internal moulds of both valves impressions of ribbing are limited to the periphery.

Ventral interior.—Delthyrium rather deep ; a pair of sub-parallel dental plates extend anteriorly to form boundaries to a sub-cordate diductor muscular impression, which is slightly crenulated anteriorly, and which bounds a centrally disposed adductor scar.

Type horizon.—Upper Llanvirn grits.

Type localities.—Quarry 240 yards N. of the Lodge, almost 2 miles S.S.W. of Llangadock, and outcrops 220 yards E. of Tan-y-garn Farm, 2 miles S. of Llangadock.

Discussion.—The new species differs from those described by Bancroft in a number of aspects, chiefly the larger size of the cardinalia, the traces of anterior extension of supporting plates, the greater convexity of the ventral valve, the limitation of internal ribbing to the peripheral zone, and the more primitive arrangement of the ribs.

Horderleyella lata sp. nov.

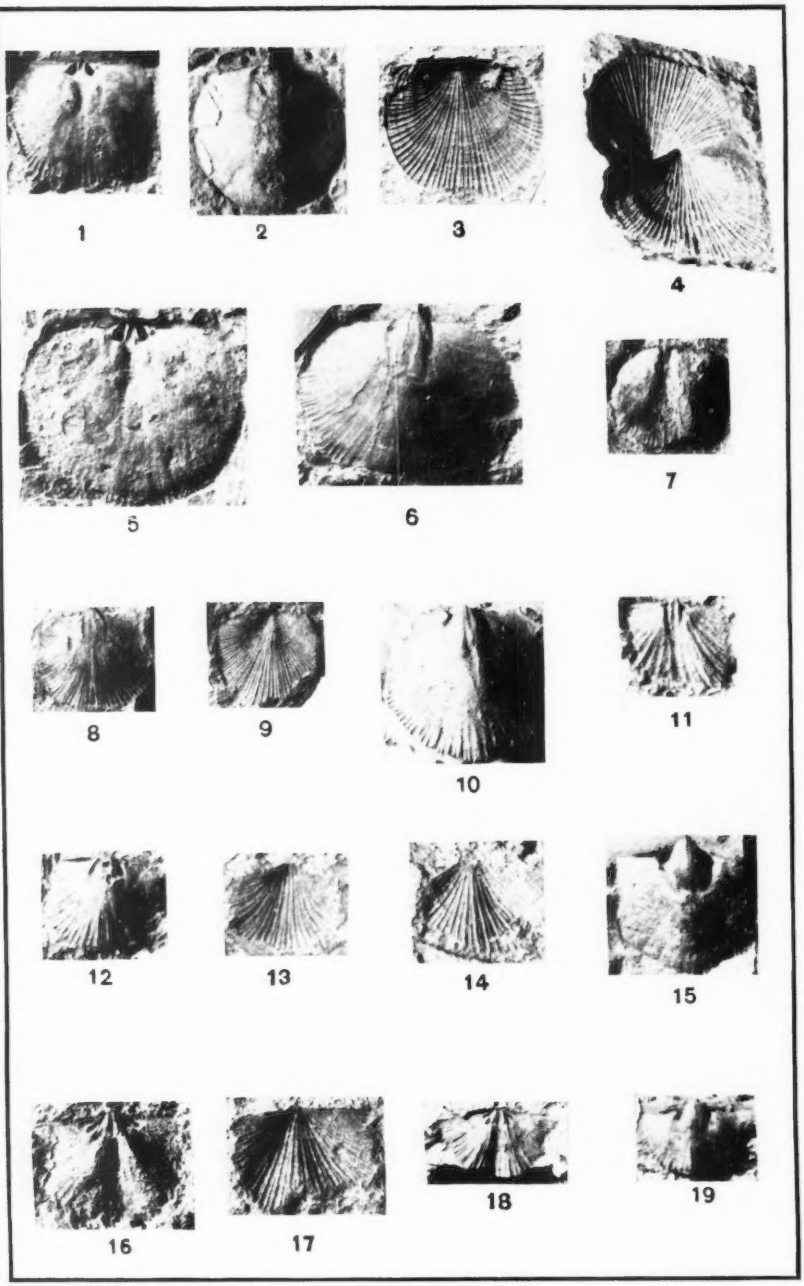
Pl. VIII, figs. 18, 19.

Dimensions.—

Syntypes.			*Length.* *cm.*	*Breadth.* *cm.*
(1)	Internal mould of dorsal valve	G.S.M. 75245a	0·7	1·2
(2)	External cast of dorsal valve	G.S.M. 75,246	0·7	1·2
(3)	Internal mould of ventral valve	G.S.M. 75,245b	0·7	1·2
(4)	External cast of ventral valve	G.S.M. 75,247	incomplete	

External characters.—A small, wide, mucronate Horderleyella. Both valves fairly strongly convex, the ventral valve more so than the dorsal valve. The dorsal valve is impressed by a deep mesial sinus on each side of which occurs a strong lateral fold with the apex to the posterior to give the shell a " shouldered " appearance. Laterally to the folds the shell is flat or almost concave. The ventral valve is carinate, with a strong mesial fold ; flat to concave postero-laterally.

Ribbing multicostellate, primitive in that secondary and tertiary branching is limited. The axes of lateral folding in the dorsal valve fall within section III.



NEW LOWER ORDOVICIAN BRACHIOPODS.

Dorsal Valve.	*Ventral Valve.*
$1\bar{a}$, 1.	$1\bar{a}$, 1, 1a°.
$2a\bar{1}$, $2\bar{a}$, 2, 2a°. $2\bar{a}$) 2a°.	2, 2b°, 2a°.
$3a\bar{1}$, $3\bar{a}$, 3, 3a°. 3a) 3a°.	3, 3b°, 3a°, 3a1°.
$4\bar{a}$, 4, 4a°. $4\bar{a} = 4a°$.	$4\bar{a}$, 4, 4b°, 4a°, 4a°) $4\bar{a}$) 4b°.
$5\bar{a}$, 5, 5a°. 5a°) $5\bar{a}$.	$5a\bar{1}$, 5a°, $5\bar{b}$, 5, 5a°.
$6\bar{a}$, 6, 6a°.	at least 3 more primaries.
$7\bar{a}$, 7, 7a°.	
etc.	

Internal characters.

Dorsal interior.—Cardinal process, long, slender, within a spindle-shaped Notothyrial cavity which is supported anteriorly by a well-marked mesial ridge. Dental sockets are fine, widely divergent, and are bounded anteriorly by a pair of crural processes, each consisting of a robust fulcral plate converging posteriorly, and a stout, moderately long, sub-parallel supporting plate. The socket and supporting plates are almost separated by long deep crural pits. Anteriorly the notothyrium is impressed by a pair of adductor pits.

Differentiation of muscle scars is obscure. Ribbing is deeply impressed on internal moulds of both valves.

Ventral interior.—Delthyrium, bounded by a pair of strong dental plates which converge posteriorly at about 80°. Muscular area truncated lozenge-shaped, weakly differentiated.

Type horizon.—Ashes of Upper Llanvirn age.

Type locality.—Ashes in the Long-wood Bethlehem, 200 yards N.W. of Bryn-towy Farm, $1\frac{3}{4}$ miles S.S.W. of Llangadock.

Discussion.—The new species differs from those described by Bancroft (1945, pp. 235–8) in its transverse form (Bancroft has described a rare transverse form of *H. corrugata* (1945, p. 237) but *H. lata* is even more transverse), its smaller size, the greater convexity of the valves, the relatively larger size of the cardinalia, and the primitive ribbing.

EXPLANATION OF PLATE.

All figures $1\frac{1}{2}$ times natural size except where indicated.

Resserella immatura sp. nov.

FIG. 1.—Internal mould of dorsal valve (G.S.M. 75,233).
FIG. 2.—Internal mould of ventral valve (G.S.M. 75,235).
FIG. 3.—External cast of dorsal valve (G.S.M. 75,234).
FIG. 4.—External casts of ventral valves (G.S.M. 75,236).

Resserella immatura var. *plana* var. nov.

FIG. 5.—Internal mould of dorsal valve (G.S.M. 75,237).
FIG. 6.—Internal mould of ventral valve (G.S.M. 75,239).

Dalmanella prototypa sp. nov.

FIG. 7.—Internal mould of dorsal valve (G.S.M. 75,248a).
FIG. 8.—Internal mould of ventral valve on the same rock specimen as G.S.M. 75,249.

FIG. 9.—External cast of dorsal valve (G.S.M. 75,249).
FIG. 10.—Internal mould of ventral valve (G.S.M. 75,250a).

Dalmanella parva sp. nov.

FIG. 11.—Internal mould of dorsal valve (G.S.M. 75,251) × 3.
FIG. 12.—Internal mould of ventral valve (G.S.M. 75,252) × 3.
FIG. 13.—External cast of ventral valve (G.S.M. 75,254) × 3.
FIG. 14.—External cast of dorsal valve (G.S.M. 75,253) × 3.

Horderleyella convexa sp. nov.

FIG. 15.—Internal mould of ventral valve (G.S.M. 75,241).
FIG. 16.—Internal mould of dorsal valve (G.S.M. 75,240).
FIG. 17.—External cast of dorsal valve (G.S.M. 75,242).

Horderleyella lata sp. nov.

FIG. 18.—Internal mould of dorsal valve (G.S.M. 75,245a).
FIG. 19.—Internal mould of ventral valve (G.S.M. 75,245b).

(To be continued.)

A "Luxullianite" from East Dartmoor

By F. G. H. Blyth

(PLATE IX)

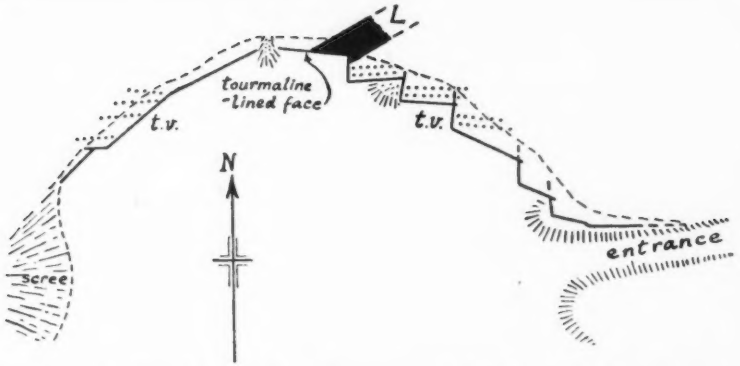
Abstract

A dyke-like mass of luxullianite type is emplaced along a line of fracture which crosses granite in a zone of pneumatolytic reddening, and is exposed in a quarry face. Extensive tourmalinization is related to post-emplacement fractures which traverse both the luxullianite and the adjacent rocks.

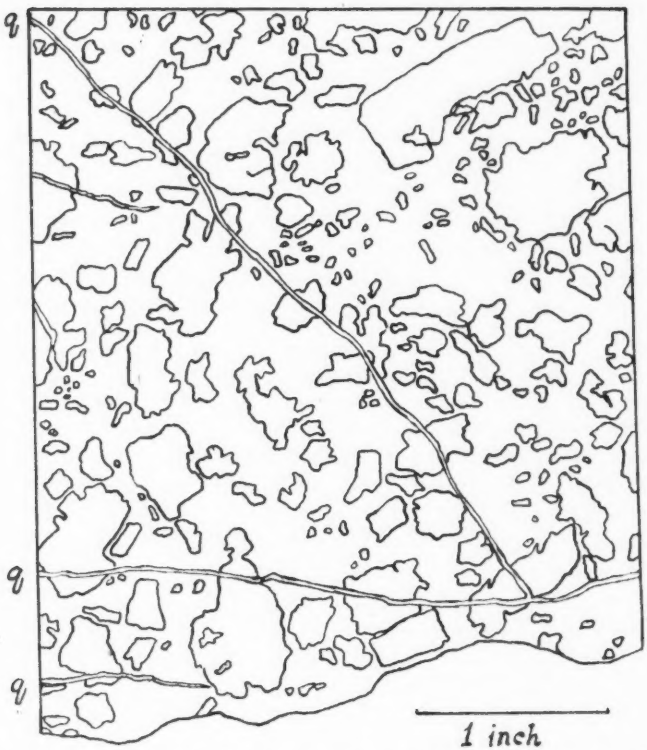
An opportunity was recently taken by the writer of re-visiting a locality near Holne, which was pointed out to him by Dr. A. Brammall some years ago, and of collecting material of luxullianite type there. The occurrence is of considerable interest and was briefly recorded by Brammall (1928, p. 38), but has remained undescribed. The following account makes special reference to the structural relationships between the luxullianitic and neighbouring rocks.

The luxullianite from the Cornish type-locality, where it is found as loose blocks or boulders, has been known for many years from the writings of Bonney (1877), Flett (1909), and others ; in a recent paper Wells (1946) has described details of its texture and microstructures. The Dartmoor "luxullianite" forms a belt of hard rock which traverses granite in the Reservoir quarry of the Paignton Waterworks, 1¾ miles to the north-west of the village of Holne. This quarry, which was opened up at the time of the construction of the dam and reservoir nearly fifty years ago, lies to the north of the Holne–Hexworthy road and within the waterworks enclosure. It reveals a section across a reddened and gently pneumatolysed zone which locally affects the normally grey granite. Within the zone of reddened rock, in the north-east corner of the quarry and intersecting the quarry-face, is the steeply-inclined dyke-like mass of "luxullianite", 3 feet to 4 feet in width. Its relationship to the adjacent rocks can be inspected here, but its continuation on the opposite (western) face of the quarry is obscured by loose blocks and slipped soil. The shape of the rock-face is shown in Text-fig. 1.

The main quarry-rock is a medium-grained, feebly porphyritic biotite-granite, which is crossed by joints trending nearly north–south and east–west. Cutting the granite also, in the northern part of the quarry, are many thin tourmaline veins which are vertical, or nearly so, and strike between N. 80° E. and east–west. In the region of the tourmaline veins the quarry-rock is reddened and carries patches of quartz-schorl aggregate. The luxullianitic band on its northern side crosses the reddened granite along a steeply dipping surface which



TEXT-FIG. 1.—Sketch plan of northern part of the Reservoir Quarry, near Holne. Reddened granite, unshaded. Luxullianitic band (*L*), black. Tourmaline veins (*t.v.*) shown by lines of dots. Width of quarry shown, about 60 feet.



TEXT-FIG. 2.—Textural outline of part of the " luxullianite " block described in the text, natural size, to show corroded felspars (enclosed areas) in tourmaline-quartz matrix. *q* = quartz vein.

strikes N. 65° E., and probably occupies a fracture or fracture-zone having this direction. The junction on the south side is less clear, but the "luxullianite" there appears to grade into, or be welded on to, the reddened granite. Some 10 feet to the south (near the entrance shown in Text-fig. 1) the quarry-rock is not reddened, but is traversed by thin tourmaline veins and carries clots of quartz and tourmaline.

The luxullianitic band is traversed by nearly east–west tourmaline-lined joints, and normal to their surfaces the rock is penetrated by coarse quartz-schorl aggregate, generally to a depth of about ½ in. but in places irregularly to more than twice that distance. These tourmaline-lined joints are parallel to the thin tourmaline veins in the granite, referred to above; the general east–west direction which they possess in common is a regional one, and is locally the trend of a zone of tourmalinization and pneumatolytic reddening which can be seen, for example, traversing the granite of the moor two-thirds of a mile to the east-north-east, in the valley of the River Dart, near Sharrah Pool. A continuation of this zone still further east would take in the quartz-schorl reef known as Leigh Tor.

The "luxullianite" itself is a hard, massive rock, of entirely different texture from that of the adjoining granite, and consists essentially of porphyritic crystals of pink felspar set in a black tourmaline-quartz matrix. The porphyritic felspars range in length from about ½ in. up to 1½ inches, and are larger than the felspar phenocrysts in the quarry granite; while they are sensibly rectangular in many cases, their edges are commonly fretted and penetrated by growths of quartz and schorl which have partly replaced them (Text-fig. 2). Sporadic areas containing smaller felspars of felspar fragments lie between the larger felspars, and may be relics of the groundmass of the original rock before it was transformed by pneumatolysis, or in some cases broken fragments of larger crystals.

Many of the felspar phenocrysts have been fractured, the several parts of a single crystal being cemented together by the quartz and schorl of the matrix. More minute cracks traversing some of the felspars are sealed by hair-like "veins" of black tourmaline. Not all the fractures are regular, but many are aligned parallel to the vertical tourmaline-filled joints which, as already stated, cut obliquely across the luxullianitic band in a nearly east–west direction. This fracturing is clearly of later date than the emplacement of the "luxullianite", and has been an important factor in the progress of the tourmalinization. In this connection it may be recalled that Wells (1946, p. 193) refers to mechanical shattering as probably an important process which, in the Cornish case, facilitated the passage of pneumatolytic material through the rock.

The tourmaline of the matrix occurs partly as stout black acicular

crystals which in thin section show blue and brown colour zoning. Larger tourmalines, developed at the expense of felspar, penetrate the felspars and in some cases enclose small ones. Many smaller tourmaline prisms lie in the clear quartz of the matrix [1]; characteristic radiating clusters of *minute* schorl needles are less abundant than in the type luxullianite. It is not proposed to describe further the microscopic details of replacement in the Holne rock, as it would largely repeat much of the description already given by other writers. Comparison of specimens shows that the proportion of felspar in the Holne rock is, on the whole, somewhat higher than in the Cornish luxullianite, though virtually equivalent areas from each could be selected. The two rocks resemble one another in that they both record the tourmalization of a granite arrested at the stage at which the large felspars had just begun to be affected.

Many of the details mentioned above are seen in a large specimen obtained from the Reservoir quarry, on which a smoothed face measuring 10 inches by 8 inches has been prepared (Plate IX). One edge of the specimen is bounded by an east–west tourmaline-lined joint, and in this part of the mass radiating groups of large acicular schorl crystals are well developed, their length in some cases reaching nearly an inch. A further feature shown by this specimen is the presence of thin quarz veins, some of which are seen in Text-fig. 2, which cross all the other structures and represent a still later fracture-system which was impressed on the rock.

Conclusions

The Holne occurrence is a tourmalinized granite of luxullianite type, and is developed along a narrow belt of severe pneumatolysis which follows a line of fracture; it is itself broken by post-emplacement fractures with which further extensive tourmalinization is associated. The following sequence can be inferred from a study of the Reservoir Quarry exposures:—

(i) Feeble pneumatolytic reddening of the quarry granite in a zone seen in the northern part of the quarry.

(ii) Fracturing in an east-north-easterly direction, followed by the injection of granitic material (bringing with it the porphyritic felspars), and its transformation by the action of tourmalinizing agents passing through the mass.

[1] A spectroscopic test on a crushed sample of the matrix revealed the presence of tin as a very strong trace, and of copper and vanadium as weaker traces. The reddened felspar showed only feeble indications of tin and copper. For making these determinations I am indebted to Mr. A. P. Millman.

"LUXULLIANITE" FROM THE RESERVOIR QUARRY, HOLNE.

(iii) Subsequent shearing of both the luxullianitic band and the adjacent reddened granite along nearly east–west vertical surfaces, which became channels for further penetration by tourmaline-forming fluids.

This sequence may have occupied a relatively short space of time during the local phase of pneumatolysis. The east-north-east direction is one locally followed by many well-developed joints, with which pneumatolytic reddening is commonly associated ; east–west fractures are also often characterized by reddening and tourmalinization.

The above conclusions point to the operation of stresses at the locality (and probably over a wider area) at a late stage in the cooling history of the granite, contemporaneous with the tourmalinization. This deduction is in agreement with the opinion expressed by Brammall and Harwood (1925, p. 329), that during the closing phase of pneumatolysis the granite of east Dartmoor was affected by stresses and the resulting fissures afforded passage-way for fluids and gases from depth.

A mechanism such as that outlined, in which intense tourmalinization is localized along a zone of fracture, provides a possible basis of explanation for other occurrences of luxullianite.

ACKNOWLEDGMENTS

The writer's thanks are due to Professor H. H. Read for facilities afforded in connection with the preparation of specimens. The surfaced block described in this paper is housed in the Museum of the Department of Geology, Imperial College, London. The photograph forming Plate IX was taken by Mr. J. A. Gee.

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EXPLANATION OF PLATE.

"Luxullianite" from the Reservoir Quarry, Holne. Reddened felspars in a black quartz-schorl matrix. Approximately natural size.

An Early List of Strata by William Smith

By J. A. Douglas and L. R. Cox

Abstract

An account is here given of the recent discovery at Oxford of a hitherto unrecorded MS. in William Smith's handwriting, giving the list of Strata as known to him in 1797 and differing in some respects from the famous list dictated by him two years later at Bath to the Rev. B. Richardson and the Rev. Joseph Townsend, a copy of which is preserved in the Geological Society's collection. The list is reproduced here in its original form and spelling, together with a number of annotations.

I.—Introduction

His nephew and biographer J. Phillips [1] has recorded how William Smith had decided by 1797 to write a treatise on the stratified rocks of this country and was considering how best to set about it. Various passages dating from this period and intended for the introduction to the proposed work have been published by Phillips [2] from the original MSS., and a further document, consisting of the greater part of this introduction as revised a year or two later, has been reproduced by one of the present writers.[3] An early and hitherto unquoted MS. in Smith's handwriting which has recently come to light at Oxford is clearly a preliminary outline of the second part of the proposed work, which it was intended should "enter into the particulars of each stratum" [4]; it indicates those geological formations which Smith had learnt to distinguish at the time it was written. The MS. is enclosed in a paper folder, bearing the words "Original Papers on Strata". The date 1797 which appears on the sheet headed "Chalk Strata" may be confidently accepted as approximately that of the entire MS. except for a few minor corrections and additions (one bearing the date 1799) which are in darker ink and thus easily distinguishable from the original writing. The MS. is therefore two years earlier than the now famous list of strata which Smith dictated at Bath to his friends Richardson and Townsend in June, 1799, and appears to be of sufficient interest to publish. It is reproduced below, with a series of annotations appended to it. The 1799 corrections are omitted except in a few places where they completely obscure the original draft. The MS. starts with a draft of the title of the proposed work, followed by three

[1] *Memoirs of William Smith*, pp. 21–22 (1844).
[2] Op. cit., pp. 18, 23–6.
[3] L. R. Cox, *Proc. Yorks. Geol. Soc.*, xxv, pp. 81–90 (1942).
[4] See Phillips, op. cit., p. 21. Phillips misquotes the MS. where it refers to the proposed contents of the first part of the work. The MS. reads: "The first . . . should treat of the structure of the earth in a general way." Phillips replaces the word "structure" by "strata".

alternative drafts (the last two crossed through) of the title of its second part.

II.—The Manuscript

Natural order of the Strata
or Structure of the Earth
deduced from practical Observations
from which are also drawn
some Remarks on the Deluge
part 2nd.

Or.

Strata of the Earth
delineated in its
Natural Order
by Wm. Smith Landsurveyor

.....

Strata of the Earth
delineated
from Observations on
Nature
by Wm. Smith Landsurveyor

.....

An accurate delineation of
Terraqueous Strata
from observations on
Nature
by W. S—— Landsurveyor

[Aug.] (1) 15th 1797 No. 1

Chalk Strata

As the immense Quantity of Chalk which composes that range of high Hills that stretch from the low Grounds in shire thro' Bedfordshire Buckinghamshire Berkshire Wiltshire and Dorsetshire to the Sea forms one of the leading features of this Kingdom—I intend to make those Hills the leading Feature of this work and by making it the first Number in my list of the Strata this being a Bed whose colour nor quality cannot be mistaken making it much fitter for that purpose than any Stratum I am yet acquainted with more especially as my observations have hitherto been confined chiefly to the Western side of these hills.

No. 2

1st Bed of Sand & Sandstone from the Chalk (2)

This Stratum of Sand found near the foot of the Chalk hills is well known as the basis or under Stratum to the Fertile Sandy Land described in Mr. Davis's (3) very sensible report on the state of agriculture in Wiltshire.

No. 3

Clay (4)

This Stratum of Clay or perhaps [sentence uncompleted].

No. 4

Stratum of fine Sand (5)

of a lightish yellow colour with thin Beds of Stone (used for paving & slate) imbeded [*sic*].

No. 5

Thin Beds of shelly Wall Stone (6)

imbed in Clay or clayey sand.

No. 6

Upper Bed of Bastard Freestone (7)

I think the Rubbishy Stone-brash Beds nr. Churchill &c which lie immediately upon a Strong Blue Clay must be the same as the bottom Beds of the Rocks near Cottage Crescent &c in Somersetshire.

No. 7

Blue Clay with Talk imbeded (8)

This Clay or rather Clayey Marl is always found to accompany the upper Bed of the Bastard Freestone in the manner described in the sections annexed. By the openings which have been made into it at the Cottage Crescent & by the side of the Wells Road at 4¼ Miles from Bath and the new Road from Bath to Bradford it does not appear to be more than feet thick of a darkish blue colour & rather lamilated. A specimen which I tried did not effervesce with ascids. The most remarkable thing which distinguishes it from several beds of the same appearance is the Natrum Selinite or Rhomboidal Selinite which I have found imbed in it at the first two places above described & the Revd. Mr an engenious friend of mine has also found it in great quantities in the same bed near Bradford.

No. 8

Yellow Clay & Clayey Stone &c (8)

This Stratum or rather Class of Stones [&] Clay alternating with one another seem to partake of the colour and quality of the Fullers Earth which lays immediately under.

[No.] 9

Fullers Earth

This very useful and highly prized Earth is found in great abundance in many of the wet sidelaying Lands near the Tops of the Hills about Bath it is never found far from that tier of springs which Issue from the upper Stratum of Freestone and the place where it lays may be easily distinguished by the poverty of the surface which I have often observed to be some of the worst Land in the neighbourhood of Bath.

No. 10

Light blue Clay (9)

1797 No. 11

Bastard Fullers Earth (9)

The Bed of bastard Fullers Earth which was found in sinking the Shafts and Cistern for the Caisson (10) at Combehay and also in the bottom of the place where the Caisson was built and which appears in different parts of the cutting thro' Blacklands Furlong Barnards and Sabins Tynings does not lay much above the under division of the Freestone or Bastard Freestone Rock in this neighbourhood.

No. 12

Lower Bed of Bastard Freestone (11)

This class of Stones or division of the Freestone Grit is composed of several thick beds of diferent degrees of hardness and of diferent Qualitis the top bed which lays immediately under the Clay is a Hard greyish Limestone full of Clayholes and generaly incrusted with petrifactions from the hard water which filters thro' the incumbent Clay and this to such a degree as to cement the Rocks together so as to be seperated with great dificulty. This is comonly called by the Quarry men burnt stuff tho it has much more the appearance of Ice and in some places assumes the shape of Isciles which are generally hollow within with a drop of clear water at the end of each.

No. 13

Sand & Sandburs (12)

This Stratum of Ferruginous Sand or Sandy Stone which in some places has beds in it hard enough for building is abt. 30 ft. thick and lays immediately under the Bastard Freestone is of a brownish yellow Colour very compact in the upper part with a little soft which calcarious matter between the joints the middle part is softer in veining with hard burs between and the joints of the sand & sides of the Burs are often deeply tinged with Feruginous matter. This part of the sand is damper than the top and tho firm enough to form Caves in without [word

illegible] is not so close and firm as the top nor so hard as the bottom beds some of which cannot be cut with Steel. These beds have large open joints between them disposed in the same regular manner as was observed in the Freestones & Chalk and serve as the Channels for that water which is the abundant supply of the numerous springs Issuing from the bottom of the sand.

No. 14
Light blue sandy stuff (13)

No. 15
Clay mixed with sandy particles & Ochre-balls (13)

No. 16
Blue Marl

No. 17
Blue or grey Lias

No. 18
White Lias

This Stratum is composed of thin Beds of fine grained stone imbeded in Clay in the same manner as the Blue Lias just described and partakes of the same qualities tho some of the Beds are nearly as white as Chalk and not much harder when first taken out of the Quarry—but when dug in the summer & properly dried makes excelent stone for building or paving Houses and is much used for both purposes in Somersetshire and if well dressed looks very neat but some Beds are much to be preferred to others. This Stone is so very comon in Somersetshire and has been so long wrought that the Quarrymen know the exact Number of Beds and have assigned to each a name—the fowllowing are the common appelations about the Timsbury & Camerton Coalworks.

No. 19
Black Marl (14)

Tho' this stratum is well known in Somersetshire and its good effects as a Manure have been long felt in diferent parts of the Country yet the above term cannot give a Stranger a correct Idea of the substance tho, it may point out it[s] properties.

No. 20
Red Ground (15)

This is the most bulky Stratum for Coal in Somersetshire having been found in some places near 30 fathoms thick and tho it is nearly of the same colour throughout it differs matterially in quality some parts of it being a sharp sand others a tenacious Clay some of a stony consistence & others a perfect flat beded Stone which may be taken up in large Flags fit for building.

21

Millstone (16)

The Millstone seems to be lodged or imbeded in the upper part of the Stratum of Red ground which runs thro' this Country and which I conceive to be of an Irony Quality. A great part of Mendip is composed of Limestone Rocks the Fragments of which it should seem fell in the way of the Irony particles united with it and formed this uncommonly hard Cement or Stratum of concreted matter which about Mendip is called the Millstone and which is evidently composed of part Limestone and part Ironstone and which perhaps if it was burnt & pulverized would form a good cement for building in water. How it comes to pass that this stone is not so thick and of a diferent form in the Measures which it should be found in about Camerton and other Coalworks as it is nearer to Mendip I am at a loss to account.

No. 22

Pennant Stone (17)

This laminated Stone of a greyish colour and gritty Quality is found under the red Ground and generally divided from it by a Bed of yellow tough Clay—called by Colliers " the tops of Cleeves ".

No. 23

Greys (18)

No. 24

Iron Stone

No. 25

Clift (19)

26

Coal

27

Coal

Many Writers have taken great pains to examine into the Component particles of Coal in order to account for its formation and finding many vegitable impressions in its concomitant Strata have thence judged it to be of vegitable origin and puzzled and confounded themselves and their readers with many unnecessary perplexities concerning it unless they could tell what formed Freestone Limestone Clay Ironstone or any other Mineral Body as well as Coal for there is not a doubt but they were all formed at the same time as the great Mass was formed of which Coal is no insignificant part not lying in heaps as many have imagined but regularly dispersed throughout such parts of the Globe as the Creator of all things thought fit to place them in.

28
Limestone (20)

III.—ANNOTATIONS TO THE MS.

(1) The margin of the sheet has been trimmed and the month cut away. A second copy of this page is, however, among the Smith MSS. and bears the complete date Aug. 15th, 1797.

(2) The Upper Greensand.

(3) Thomas Davis of Longleat, Land Steward to the Marquess of Bath and author of the Board of Agriculture Report, " General View of the Agriculture of Wiltshire."

(4) Probably the Gault. At this period Smith had met with this formation in a brickyard at Crockerton, south-west of Warminster, and in an exposure near the Black Dog Inn, south of Standerwick, on the Warminster–Bath road. He may also have seen exposures of the Oxford or Kellaways Clay and confused them with the Gault.

(5) No doubt No. 4 referred to some exposure of beds of the Forest Marble series. The brief description given does not quite tally with the typical Hinton Sand of the Hinton Charterhouse district, which constituted Stratum 4 of Smith's 1799 list.

(6) The Forest Marble. It may be noted that this name is not used in the present list, although introduced in the 1799 list.

(7) The Bath Stone. When this MS. was written Smith was living at Cottage Crescent, on the northern flank of Odd Down, Bath, and there were several Bath Stone quarries in the immediate neighbourhood. He goes, however, astray in correlating this formation with the freestone (Chipping Norton Limestone) quarried near his native village of Churchill, in North Oxfordshire. In a note added in 1799 to the present MS. he goes still further astray in correlating the Bath Stone with the freestone (Inferior Oolite) of Frocester and Birdlip Hills, in the Cotswolds.

(8) Formations 7 and 8 are now grouped together as Upper Fuller's Earth Clay. Smith knew the Fuller's Earth in greater detail than any other formation, for Cottage Crescent was built upon it and much of his canal passed through it.

(9) Formations 10 and 11 are the Lower Fuller's Earth Clay.

(10) Robert Weldon's ingenious but unsuccessful Caisson on the canal at Combehay is described and illustrated in J. Billingsley's " General View of the Agriculture of the County of Somerset " (1797), p. 317, pl. xv.

(11) The Inferior Oolite.

(12) The Midford Sands.

(13) Formations 14 and 15 of this list are omitted in the 1799 list, where they are presumably included in the Blue Marl.

(14) The Rhaetic.

(15) The Keuper Marl.

(16) The Dolomitic Conglomerate.

(17) As in the 1799 list, the Pennant Stone is placed above the Coal Measures, although Smith well knew that in the collieries near High Littleton, where he had worked for several years, the Coal Measures are overlain directly by the red marls of the Trias. There are, of course, two series of Coal Measures in Northern Somerset, one above and one below the Pennant Grit.

(18) A local miners' term for hard carbonaceous grit of the Coal Measures.

(19) A local miners' term for hard, laminated, black, or grey shale with plant remains.

(20) The 1799 list ended with the Coal. It is, therefore, interesting to see that in 1797 Smith correctly placed the Carboniferous Limestone below the Coal Measures, although a few years later he was less certain of its position. (See Cox, *Proc. Yorks. Geol. Soc.*, xxv, p. 29 (1942).)

IV.—Concluding Observation

The list of formations in the MS. reproduced above compares very closely with that dictated by Smith to Richardson and Townsend in 1799.[1] The differences between the two lists may be summarized as follows.—Stratum 5 of the 1799 list (" Clay "—probably a clay of the Forest Marble series, as the position, above the Forest Marble, is wrong for the Bradford Clay) is omitted in the present list. Stratum 10 of the present list is omitted in the 1799 list, where it is, no doubt, included in " Bastard Fuller's Earth and Sundries ". Strata 15 and 16 of the present list are also omitted in the 1799 list, where they are probably included in the Blue Marl. Stratum 24 (" Ironstone ") is similarly omitted in 1799 and probably included under " Grays ". Two numbers (26 and 27) are allotted to the Coal in the present list, and only one in the 1799 list. Stratum 28 (" Limestone ") is, as already mentioned, omitted in the 1799 list.

It is thus clear that the main details of the succession around Bath which Smith gave in 1799 had already been known to him for several years—probably since 1793 or 1794. From 1794 to 1799 he was occupied with the exacting duties of Resident Engineer to the Somerset Coal Canal Company, and his geological observations were necessarily confined to the formations excavated during the construction of the canal and such exposures as he could examine between Bath and the

[1] This list has been reproduced several times, e.g. by Smith himself, *Memoir to the Map and Delineation of the Strata*, table facing p. 8 (1815), and by T. Sheppard, *Proc. Yorks. Geol. Soc.*, xix, table facing p. 127 (1917).

canal, and on very occasional journeys along the Bath–Warminster road to see his friends Thomas Davis, of Longleat, and the Rev. Benjamin Richardson, then living at Woolverton. It has often been pointed out that the 1799 list, like the present one, omits all the upper part of the Jurassic together with the Lower Greensand, the reason being that the Gault rests directly on Oxford Clay at the only place (near the Black Dog Inn, south of Standerwick) where its outcrop crosses the Bath–Warminster road, and the exposures in the vicinity were insufficient to enable Smith to discriminate between the two clay formations. The Gault overstep is well seen at the present time in abandoned workings for Westbury Iron Ore near Bremeridge Farm, between Dilton Marsh and Penleigh, as demonstrated by Mr. G. A. Kellaway to the International Geological Congress party who visited the area recently. At the eastern end of these workings the Gault rests on Kimmeridge Clay, which itself overlies the iron ore, of Upper Corallian age. A little further to the west the Gault rests directly on the iron ore, and at the western end of the workings the ore has itself been cut out by the unconformity, and the Gault rests on Lower Calcareous Grit. Further west there is no trace at all of Corallian rocks. No doubt had the Westbury Iron Ore been worked in Smith's time he would have made a détour from his customary route early in his investigations to study its geological position ; this ore was, however, first worked in 1856.

As events were to prove, Smith's 1799 list of formations was somewhat premature. From that year onwards he was no longer tied to his canal work and had many more opportunities to explore the countryside around Bath and to travel to other parts of England. Such formations as the Bradford Clay, the Cornbrash, the Kellaways Rock, and the " Clunch " [Oxford] Clay were soon discovered and assigned to their correct stratigraphical positions. The Corallian rocks and Kimmeridge Clay of western Wiltshire and the Lower Greensand of Seend also became known to him, although it was not until the earlier copies of his great map of 1815 had been printed and distributed that the succession of the Upper Jurassic and Lower Cretaceous formations was correctly unravelled.

Classification and Phylogeny of the Tetrapods

By Baron Friedrich von Huene (Tübingen)

(PLATE X)

Abstract

Primary divisions of the lower tetrapods are believed to be expressed in the structure of the vertebrae, which represent an earlier formation embryologically than the skull. On this and other grounds the Urodeles are referred to an isolated group, the Urodelomorpha. Already in the embolomerous forms of the Carboniferous is seen the cleavage into Loxembolomeri (Batrachomorpha) and Anthrembolomeri; from the Anthrembolomeri again are derived the Diadectomorphs (Reptiliomorpha) and the Captorhinomorphs, the latter the ancestors of the Theromorphs (including Mammalia), the Archosauromorphs and the Neosauromorphs. From Triassic times onwards active evolution and the production of new types becomes progressively restricted, with the principal exception of the several Theromorph lines by which it is transmitted to the Mammalia and finally Man.

In former times animals were classified according to their mode of life and external appearance; more recently, especially since Linné, one attempts to express in the system so far as possible their anatomical relationships. This is primarily the task of the zoologists, whom palaeontologists have to follow. But among the lower tetrapods the number and variety of fossil forms so greatly exceeds that of living forms that palaeontology must itself supply a convincing expression of their relations. About a hundred years ago Richard Owen opened the way that others have followed, and five decades have passed since the fundamental work of Zittel's *Handbook* and the *Textbook*, which has appeared in several languages but few editions. One of the most modern of the numerous later attempts is Romer's *Vertebrate Paleontology*, where special attention is paid to phylogenetic relations. In the same direction, the writer intends to demonstrate some specially significant aspects of tetrapod classification.

Some basic points of phylogeny are reflected in the earliest individual development. The first to be formed is not the skull but the dorsal nerve cord, and the notochord, with supports surrounding both of them. Only subsequent to the formation of the nerve cord is the brain formed, with its protecting organs. Therefore, the writer assumes that the primary divisions of the tetrapods will be reflected in the basic structure of the vertebrae. In this matter, Gadow (1896) showed the way; through him we know that embryologically each vertebra begins as two neural arches and two chordal arches. The oral one of the latter arches, the basiventral, ossifies as the intercentrum and, in the tail, the chevron grows out from it. The caudal chordal arch, the interventral, becomes the pleurocentrum of the definitive vertebra. This

allows the possibility of recognizing from which of the two chordal arches the definitive ossified vertebral centrum has resulted when (as commonly occurs) there is but a single bone. If the haemal arch grows out of the ossified vertebral body, then the latter is the intercentrum (basiventral) ; but if there are special chevrons between the vertebrae in the tail, then the centrum is a pleurocentrum (interventral).

Considering the fossil lower tetrapods, it is found that in all Urodeles the vertebral body and chevron in the tail form a single piece, but in all reptiles the vertebral body and chevron are two pieces. It is, therefore, inconceivable that, for instance, a Permian Labyrinthodont could be descended from a Carboniferous Urodele. It might appear unnecessary to refer to such general points, but the same principle is true also of younger phyletic branches such as the rhachitomous and gastrocentral groups.

In two groups both of the chordal arches play an almost equally important part in individual development. In one of these groups both of the arches develop quite equally during Carboniferous times and the vertebra becomes embolomerous. In the other group the caudal arch ossifies very little later than the oral one already in Carboniferous times and the vertebra becomes rhachitomous ; this tendency increases throughout Permian times, so that by the Upper Trias the basiventral alone ossifies without leaving any space for an ossified interventral (Stereospondyli). In the first-named group the reverse tendency operates, for to the embolomerous Anthracosaurs (Anthrembolomeri) the Seymouriamorphs are closely related, and here the basiventral ossifies a little later than the interventral arch, and the pleurocentrum becomes the essential vertebral body (gastrocentral vertebrae). This is still more the case in all other reptiles, and the intercentrum only appears as a minute bone in the presacral region, or is even unossified. So we see in the development of the bony vertebra the tendency to reduce the double chordal arch to a single one. The significance of this lies in the fact that delay in the ossification occurs either in the oral or in the chordal arch. This is the definitive fate for all later descendants. It is, therefore, unthinkable that any direct relationship between these two main branches could occur at any later time. The original cleavage must have occurred at some very early date (? Upper Devonian) as a differentiation of these tendencies while their actual appearance was still unchanged.

Regarding the first of these divisions, Jarvik (1942) has demonstrated that the Urodeles, on the one hand, and the Stegocephalia, on the other, come from two different branches of Upper Devonian Crossopterygia ; according to his detailed investigations the Urodeles from the Porolepiformes and the Stegocephalia (and also the reptiles) from the Osteolepiformes. The Urodeles possess pseudocentral

vertebrae, a structure without parallel in other tetrapods. Therefore the Urodeles are to be considered as quite isolated descendants of the Crossopterygians, the Urodelomorphs. All other tetrapods, descended from osteolepiform Crossopterygians, might be called Eutetrapoda. Watson (1940) and Jarvik have shown that the Anura are derivable from early Labyrinthodonts. In the Anura, the circumchordal ossification in both the chordal arches is so much retarded that the united neural arches have time to grow ventrally and even surround the notochord. This produces the notocentral structure of the Anuran vertebra. The Upper Devonian Ichthyostegalia apparently form an early side-branch of the Stegocephalia (Loxembolomeri) in which the long interparietals and tabulars of the Crossopterygians are already shortened to half their size ; and this is the origin of the neck.

The second division, also beginning embolomerous with the Carboniferous Anthracosaurs (Anthrembolomeri), differs in several points of skull morphology. They have no rostral (internasal) bone ; the septomaxillary at first does not appear externally in the skull (in Urodeles it does not exist at all but is replaced by an anatomically different bone, the nariale) ; there is usually an intertemporal at first, which is absent in the Loxommids (with one exception) ; the medulla oblongata and the neurocranium are much shortened ; and the interparietal is always narrower than the parietal, so that the tabular is in contact with the parietal. In the Stegocephalia, the interparietal is always broader than the parietal. The parasphenoid does not embrace the otic capsule to any greater extent than it does in the Stegocephalians, and the inner ear is bounded by the opisthotic and prootic. The stapes goes from the fenestra ovalis to the quadrate and not to the otic notch of the skull roof as in the Stegocephalia. The long vomer is relatively narrow and borders the median side of the palatal nostril, while in the Stegocephalia it is relatively broad, pushing the choanae further apart. In the older representatives of this group the septomaxillary does not appear on the exterior of the skull.

The first-mentioned division constitutes the Batrachomorpha, the second division the Reptiliomorpha (Plate X). Originally the skull in both these divisions was anapsid. From Lower Carboniferous times, both groups run parallel to each other, and in several respects the differences between them increase with the passage of time. The Urodeles remain throughout their life in a larval condition in respect of exterior gills ; the Batrachomorpha pass through such a larval stage during some part of their life ; while only the most primitive orders (Anthrembolomeri and Seymouriamorpha) of the remaining groups pass through a short larval stage in youth.

The Reptiliomorpha are represented in the Lower Carboniferous by the Anthrembolomeri and their last representatives (*Archeria*, etc.)

reach the Lower Permian. The date of the real beginning of the later branches (orders) cannot be determined with any precision as we have only a limited number of sedimentary basins where remains of these animals occur. The Seymouriamorpha are known essentially from the Lower Permian ; the post-parietal part of their skull is much shortened. Amongst them are also semiaquatic forms with flattened skulls, such as *Phaierpeton* and *Kotlassia* ; another form, *Lanthanosuchus*, even has an opening in the temporal region. A primitive order are the Microsaurs, many of which are adapted to aquatic or semi-aquatic life. The post-parietal portion of the skull is shortened in most of them, so much so that the tabular row in some of them is wholly or partly pushed to the occipital wall ; but in the terrestrial forms, such as *Pantylus*, these elements occupy a larger space. The large size of the supratemporal is still characteristic of them, but the intertemporal has already disappeared. There is no longer an otic notch in the roof of the skull. The brain capsule is shortened and in the palate occurs a moderate-sized interpterygoid opening.

Another very primitive order, much obscured by extreme adaptation to a marine habitat and not known before the Lower Trias, is the Ichthyosauria. Some time ago, I considered that these were derived directly from the Anthrembolomeri, but I am now inclined to regard them as descended from some unknown semi-aquatic ancestors which might stand a little higher than the Seymouriamorphs. The middle ear of the Ichthyosaurs is organized as in Microsaurs, Diadectomorphs, and Seymouriamorphs. Their most primitive representatives are still nearly anapsid (*Mixosaurus*). The temporal opening, originating in connection with the development of a rostrum, is situated between parietal, prefrontal, and supratemporal ; I have called it *metapsid*, as distinct from the *synapsid* temporal opening between parietal, postorbital, and squamosal in the Theromorphs. Like all higher Reptiliomorphs, the Ichthyosaurs possess a single coracoid separate from the scapula ; but all Batrachomorphs have a fused scapulo-coracoid ; only the most primitive Reptiliomorphs, the Anthracosaurs, retain this latter form, and originally the Theromorphs have two coracoids.

The Diadectomorphs are typical terrestrial Reptiliomorphs. Their characters are sufficiently well-known through the recent work of Olson (1947) ; they have an otic notch, a tabular row, and even an intertemporal in the roof of the skull.

The Procolophonia and the Pareiasauria must have originated from the Diadectomorphs in the Permian, as also the Chelonia. These orders show different specializations ; only the Chelonia survive, thanks to the protection afforded by their carapace. Carnivores probably destroyed the other primitive orders.

The Captorhinomorphs are a parallel branch to the Diadectomorphs. They early lose the last vestige of an otic notch and the tabular row migrates to the otic wall. The supratemporal, too, is about to disappear. In a few of their late representatives a vestigial synapsid temporal opening appears (*Milleretta*, *Millerosaurus*). It is here that the Pelycosaurs take their origin in Upper Carboniferous time. Early sphenacodonts (Pelycosaurs) form the root of the Therapsids, and at the same time *Araeoscelis* is the beginning of the Protorosaurs. From another point in the primitive Captorhinomorphs, the Younginids (with two temporal openings) stand out as a beginning of the Thecodonts with their later Mesozoic descendants and, parallel to the Thecodonts, the Rhynchocephalia. Finally, the Squamata probably also arose from the Captorhinomorphs, through *Broomia* and *Prolacerta*.

The Theromorphs, in contrast to the Reptiliomorphs, are characterized by a *synapsid* temporal opening and the tabular row with few primitive exceptions has been pushed on to the occipital wall. In the post-cranial skeleton the Theromorphs have two coracoidal elements, which become united in the Triassic. A compact, independent aquatic parallel to the Pelycosaurs is the geographically restricted Lower Permian group of the Mesosaurs.

Pelycosaurs have been exhaustively treated by Romer and Price (1940) and the derivation of the Therapsids from early Sphenacodonts has been dealt with by the same authors. Somewhere near the root of the Therapsids in the Lower Permian also, the Placodonts and the Sauropterygians may be supposed to have diverged, though they are unknown before the beginning of the Trias.

In Upper Triassic and Lower Jurassic occurs the transition from Therapsids to Mammalia. According to Olson (1944), the oldest mammals in several classes must be looked on as a continuation of several distinct lines of Therapsids. On this view, which was forecast by Broom, the unity of the Therapsida does not end with the extinction of the Ictidosaurs, and the unity of the mammals does not begin with the first " mammals " as something absolutely new ; but rather the flow of families, lines, and (in later times) orders is advancing from Triassic into Jurassic and later periods. If the mammals had arisen from one single point in Therapsid stock (as, for instance, the Ictidosaurs), as was believed until recently, the conception would be quite different—the sudden birth of a new class. But this does not now seem to be the case. A more or less broad flow of lines passing (as it seems) from Triassic to Jurassic, with an earlier phase characterized by a more primitive stage in development of the ear and jaw and teeth (which is called " reptilian ") and a more advanced phase of these characters (called " mammalian ") is the present-day conception of the problem.

The Sauromorphs, which in Permian times originated from early Theromorphs, are characterized by two temporal openings, the upper one of which develops between the same bones as in the synapsid Pelycosaurs (postorbital squamosal and parietal) ; the lower one is bordered below by jugal and quadratojugal. Thus is produced the *diapsid* skull, first seen in the Eosuchia, leading on to the Thecodonts and all the great Mesozoic orders, the Saurischians, the Ornithischians, the Crocodilia, the Pterosaurs, and the birds, all of which originate in the Trias. A small and compact parallel-branch of the Thecodonts, the Rhynchocephalians, survive to the present day. They are rather an archaic order, and in contrast to the Thecodonts have retained the supratemporal. But Thecodonts and their descendants are all progressive.

A second division of the Sauromorphs, as mentioned above, comprises the Protorosauria and the Squamata. These possess a single temporal fenestra, bordered as in the synapsid Theromorphs, but having a tendency to loosen the quadrate by an increasing notch from the lower border between jugal and quadrate. This I named the *katapsid* skull. They constitute the Neosauromorpha, as distinct from the first division or Archosauromorphs.

In the view here expressed, the classification of the Tetrapods appears in its main features to be the result of several bifurcations. Firstly, from the osteolepiform Crossopterygians come the Embolomeres, which at the beginning of the Carboniferous are represented by the Loxembolomeri and the Anthrembolomeri. The former and their descendants constitute the Batrachomorpha ; the latter and their descendants begin with the Reptiliomorpha. In the latter again, the principal bifurcation is as between Diadectomorpha with their Reptiliomorph descendants and the Captorhinomorphs, from which come not only the Pelycosaurs and all other Theromorphs but also the Sauromorphs.

In Carboniferous and Lower Permian times the main branching continues and the Triassic is still a time of active evolution. But the further one proceeds in the Mesozoic, the weaker becomes the force of fresh production. Only the Squamata develop actively in the Cretaceous, when most others have reached a terminal stage of phyletic life, foreshadowing their end. Among reptiles, active evolution in relatively late times is restricted to the main lines of Theromorphs, especially transmitted through their mammalian descendants to a much later period, and finally to the origin of man and the human spirit.

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EXPLANATION OF PLATE

Phylogenetic tree illustrating the interrelations of the Tetrapods.

CORRESPONDENCE

EAST ANGLIAN DRIFTS

SIR,—Dr. Carruthers' recent letter in the *Geological Magazine* (1948, lxxxv, 367–8) is a stimulating challenge to the orthodox interpretation of the glacial deposits, but his conclusion that the boulder clays of East Anglia were laid down by a single composite ice-sheet does not fit the facts.

In the first place I understand that he considers that uncontorted sands below a boulder clay indicate deposition which accompanies the bottom melt of a stagnant ice-sheet. One place where this interpretation is wrong is at the well-known pit at Chillesford Church, where boulder clay rests on undisturbed Chillesford Beds which are certainly not connected with the bottom melt of any ice-sheet. This and other similar sections prove that it is possible for unconsolidated deposits to remain intact below an ice-sheet.

It is possible that some phenomena, especially within the Cromer Till Series, may exhibit the effects of bottom melt, fallen roof, and other characteristics of melting ice, but there is no reason to enlarge these interpretations into a theory which considers the extremely various boulder clays of East Anglia as overthrust layers in one ice-sheet. Dr. Carruthers admits disturbance of underlying beds by the " Cromer Tills of the Norfolk Coast " and by the " Lowestoft (Chalky-Jurassic) Till around Ipswich ", thus confirming some degree of readvance for at least two separate stages in East Anglia, and yet he proceeds to the contrary opinion that the whole East Anglian sequence is monoglacial. That these two tills belong to separate stages is proved by sections at Corton and elsewhere. Incidentally, as Boswell has shown, much of the folding in the Ipswich area was caused by the Gipping (" Upper Chalky ") Ice-sheet.

On the glacial evidence alone, therefore, there is no support for the theory that all the boulder clays of Norfolk and Suffolk belong to one glacial episode. The fossil evidence from certain horizons also disproves such an idea. The unique marine fauna of the Corton Beds, as proved long ago by Wood and Harmer, show that these deposits represent a change of facies and climate, as compared with the glacial beds above and below them ; and they cannot be explained as an included mass in a single ice-sheet, as they extend over an area of about 1,000 square miles, and in places attain a thickness of 80 feet. As regards Hoxne, Dr. Carruthers questions whether there has been a readvance of the ice in England after the freshwater beds of that site had been laid down. This problem has been debated for many decades, but it

seems to me that the gravel above the temperate deposits at Hoxne can be traced westward into Paterson's " Upper Boulder Clay " in the Breckland (Gipping Glaciation), and this geological evidence is supported by the finding of implements of Hoxne type below that boulder clay at West Stow, Elveden, and other places in the Breckland area.

As to the Hunstanton Boulder Clay, I would add that the old section (now closed down) at the Gasworks Pit at Hunstanton showed most clearly how the March Gravels had been ploughed into and partly incorporated by the overlying Hunstanton Boulder Clay, which is, according to Dr. Carruthers' theory, a proof of readvance. In general, it seems to me that there is abundant proof that the boulder clays of East Anglia were not formed from a single composite ice-sheet.

D. F. W. BADEN-POWELL.

UNIVERSITY MUSEUM,
OXFORD.

6th May, 1949.

INDICATION OF GEOLOGICAL SITES

SIR,—Referring to Dr. Rastall's plea for greater accuracy in the use of place names by geologists (*Geol. Mag.*, 1949, lxxxvi, 110), and Mr. Percy Evans's, for full use of the National Grid in Great Britain (*Geol. Mag.*, 1948, lxxxv, 242), may I urge the use of geographical co-ordinates to indicate geological sites throughout the world? The advantages are so great that it is surprising to find this obvious method seldom adopted in the literature.

My experience in the Middle East, the Mediterranean area, French North Africa, and North-East Africa is that place names there are often of very limited value for the purpose. Many names that one learns in the field are not shown on any published map, and conversely, a common name may be found in more than one place on a given map. Neither Arab nor Somali, for example, is by nature imbued with that need for accuracy that is desirable in scientific work, and in their scantily populated countries location on the ground of some of their place names seems to a European, partly from the nature of the case, to be regrettably imprecise.

Grid references are excellent when the appropriate map is available, but obviously useless without it. On different maps of Somaliland, moreover, there are two quite separate grid systems, employed respectively by the War Office; and by East Africa Command during World War II. Such a case is probably not unique.

Geographical co-ordinates are most generally useful, though certain foreign maps printed with co-ordinates in grades, or with a prime meridian of Paris, Rome, Ferro, or other of the couple of dozen that are used in various parts of the world, may give rise to error unless these peculiarities are observed and allowed for. But the latitude and longitude (referred to Greenwich) of any point on the earth's surface can be easily plotted on nearly all maps, to as great an accuracy as required. General use of this method, which I have tried to apply for the past twenty years, would lead to greater accuracy and conciseness of indication, and would often save time and measureless exasperation to all who wish to pin-point a locality from the data of others.

W. A. MACFADYEN.

HOPE'S GROVE,
TENTERDEN, KENT.

8th May, 1949.

REVIEWS

PHYSICAL GEOLOGY. By C. R. LONGWELL, A. KNOPF, and R. F. FLINT. xvii + 602, with 365 text-figures. New York : John Wiley and Sons, Inc. London : Chapman and Hall, Ltd. Third edition, 1948. Price 30*s*.

The first and scond editions were published in 1932 and 1929, as a successor to Part I of *A Textbook of Geology*, by Pirsson. The present edition has again been revised and improved in text and illustrations. The principal addition is a new chapter 2, entitled " Method and Scope of Geologic Study ". This sets out to illustrate scientific method by the concepts of isostasy and geological time, so introducing these ideas at an early stage. The result is disappointing. The material in the first two chapters is good, but could be rearranged with advantage. However, this book continues to deserve commendation as one of the most reliable and well produced elementary texts.

W. B. H.

GEOLOGY AND SCENERY OF THE COUNTRYSIDE ROUND LEEDS AND BRADFORD. by H. C. VERSEY. pp. 94, with 19 figures. London : Murby and Co., 1948. 10*s*.

The frontispiece of this book shows the Leeds–Bradford district to include the outcrops of the Mountain Limestone in the upper parts of Airedale and Wharfedale, the Millstone Grit and Coal Measures stretching south to beyond the River Calder, and the Permo-Triassic limestones and sands which overlie these rocks in the east.

The work is introduced by a concise account of the science of geology, written with the minimum of technical terms, and with a wealth of local allusions. Chapters II to V deal respectively with the country occupied by the Mountain Limestone, the Millstone Grit, the Coal Measures, and the Magnesian Limestone, the first half of this last chapter being actually an account of the Carbo-Permian structures. Chapter VI (Rivers and Glaciers) is especially notable for its summary of the Pleistocene history of the region. The last chapter (Selected areas for field study) contains itineraries for thirteen excursions ; it concludes with Hints for Further Study, in which a few selected publications are recommended, a general bibliography being excluded, perhaps wisely in view of the very extensive literature on this area.

The book, which embodies the results of a great mass of research work, covers the ground with admirable balance and thoroughness. It is attractively illustrated with simple line-diagrams ; but among these certain of the cross-sections could with advantage have shown some indication of the vertical exaggeration, and the frontispiece would be improved by a scale. A few statements might be questioned, such as the reddening of underlying rocks by downward percolation of iron from the Permian (p. 54), and the alignment of coal workings to the " bord " (p. 44). *Carbonicola ovalis* (p. 43) should be *C. communis*, and there are more than four marine bands in the Coal Measures of the area.

Despite some slight trouble with the symbol for vertical strata on p. 13, and with numbering of geological maps on p. 88, the publishers have done their job well.

W. E.

DEEP BORING THROUGH ORDOVICIAN AND SILURIAN STRATA AT KINNEKULLE VESTERGÖTLAND. By B. WAERN, P. THORSLUND, and G. HENNINGSMOEN. *Bull. Geol. Inst. Upsala*, xxxii, 1948, 337–474.

The Lower Palaeozoic section of Kinnekulle mountain has long been known to geologists. The sedimentary rocks are capped by a diabase sill which covers an area about half a mile in diameter, and is 27 m. (90 feet) thick ; it is to this hard capping that the relatively soft rocks owe their

preservation. In 1941 a borehole at Norra Skagen east of the summit proved the section from the Middle Ordovician to the top of the Lower Cambrian ; in order to complete the section the Geological Institute of Upsala decided to put down another borehole " as a duty to Swedish geology ". This was sited on the west side near the Kullatorp spring, and was put down by the Swedish Diamond Rock Drill Company to a depth of 88·56 m. (290 feet) in June, 1944 ; the diameter of the core was 70 mm. It started about 22·7 m. (75 feet) below the base of the sill, and penetrated the Llandoverian rocks as well as nearly 50 m. (164 feet) of Ordovician rocks nearly to the base of the Chasmops Series. The depth of the boring was designed to give a considerable overlap in the Ordovician between the Kullatorp and the Norra Skagen boreholes.

An account of it has now appeared. The lower part of the section from 63 m. to 88·56 m. (Chasmops Series) is described by Dr. Per Thorslund, the middle part from 3·515 m. to 63 m. (Tretaspis Series) by Mr. Gunnar Henningsmoen, and the upper part from the surface to 35·15 m. (referred to the Silurian) by Mr. Bertil Waern, who also planned and supervised the boring operations. The purpose of this note is to call attention to certain features of the section which are of particular interest to British geologists.

Chasmops Beds.—The *Chasmops* Series consists of grey mudstones and shales with a few beds of limestone mainly in the lower part ; black shales with *Dicranograptus clingani* occur near the top. Numerous beds of bentonite, one of the about 1·8 m. thick, which occur between 66 m. and 76 m., are believed to represent fine volcanic dust from some distant area. The shelly fauna appears to contain many forms allied to those that make their appearance much later in the Ashgillian of England and Wales, such as *Phillipsinella* cf. *parabola*, *Trinodus*, *Remopleurides*, etc. Comparison with the borehole at Norra Skagen suggests that the base of the *Chasmops* beds was not reached at Kullatorp, and the two boreholes together indicate that the Ordovician sequence is about 112 m. (367 feet), excluding the *Dalmanitina* beds at the top (see below). In the lower part of the Kinnekulle section, *Nemagraptus gracilis* occurs, and it is suggested (p. 361) that the *Chasmops* Series is represented in the Caradoc or Lower Bala of Britain. It is tempting to correlate as the author does (p. 362) the bentonite beds which occur just below the black shales of the *Dicranograptus clingani* zone with " Caradocian periods of vulcanicity . . . for instance Snowdon and Llanwrtyd ". The Snowdonian rocks occupy a closely corresponding position, but the Llanwrtyd rocks are probably older.

Tretaspis Beds.—The black shales (1 m.) with *D. clingani* are overlain by 12 cm. of a dark grey, slightly argillaceous and glauconitic limestone, which near the top is phosphatic and pyritic. This bed is overlain by black shales (2 m.) with *Climacograptus styloideus* which correspond with the *Pleurograptus linearis* zone in Britain. The basal part of the shale contains a shelly fauna which is quite different from that of the *Chasmops* beds below. The underlying limestone contains in its lower part *Tretaspis ceriodes*, but the boundary between the *Tretaspis* and *Chasmops* beds is drawn at a somewhat higher level and below a layer 15 cm. thick of dark marlstone containing scattered grains of glauconite. It is interesting to note that phosphatic beds occur in Wales in several places (Penygarnedd, etc.) immediately above black shales of the *D. clingani* zone.

The *Tretaspis* beds are mainly mudstones and shales, with one bed of a peculiarly veined limestone (Masur limestone) 1·2 m., which yielded no recognizable fossils. The mudstones are brownish-red with a few thin bands of green ; two narrow bands of bentonite were noted in the upper part. The uppermost beds (2·65 m.) are described as the Grey or Top Sandstone, which is separated from the overlying *Dalmanitina* beds by a sharp break ; from the lower half of this sandstone *Dalmanitina mucronata* is recorded. It is interesting to note that *Tretaspis seticornis seticornis* and *T. granulata bucklandi* occur in the same order as they apparently do in Britain.

A curious speckled shale occurs near the junction of grey mudstones and

black shales and as noted (p. 384) a speckled zone is found at the base of the *Phillipsinella parabola* beds in N. Wales. This curious rock type seems to resemble the " mottled beds " which occur at various horizons in the Ordovician and Silurian mudstones of Wales, viz. base of the Ashgillian (Berwyn ; Sholeshook and Crymmych, Pembrokeshire) ; higher in the Ashgillian (Abercwmeiddaw beds) ; base of the Llandoverian (*Glypto. persculptus* beds) ; base of Middle Llandoverian (*Meso. magnus* beds) ; top of Llandoverian (*Mono. crenulatus* beds). They appear in all cases to accompany a change of physical conditions in the area of deposition. There may be more than one kind of mottling—one due to stirring up of black mud during the deposition of grey muds and the other possibly due to organic agencies.

Silurian.—In the rocks down to a level of 35·15 m. (115 feet) which are assigned to the Silurian three series are recognized in ascending order, viz. the *Dalmanitina* beds, the *Rastrites* beds, and the *Retiolites* beds. The main part of this section consists of shales and mudstones, but limestones were met at certain horizons. The black shales usually yielded graptolites ; the mudstones, which are lighter coloured, and some of the limestones contain a shelly fauna. That of the mudstones consists mainly of small specimens and does not represent a fully developed shelly facies.

The Silurian facies in its small thickness and suggestion of several breaks in sedimentation, presents resemblances to the developments of the Llandoverian rocks of the Lake District and the Austwick area, but the graptolitic beds can also be compared closely with those of Central Wales. In fact, the lithology of the Silurian rocks suggests comparison during the Llandovarian with the English and Welsh part of the Lower Palaeozoic geosyncline rather than with the Scottish part.

The Ordovician-Silurian Boundary is drawn at the base of the *Dalmanitina* Beds at a depth of 35·15 metres. There is an obvious hiatus at this level between them and the underlying beds as shown by the sharp contact and the abundant angular chips of shale in the lowest limestones of the *Dalmanitina* beds. Unfortunately there is some uncertainty regarding the age of the sandy beds (2·65 m.) called the Grey or Top Sandstone, which intervenes between the *Tretaspis* Series and the *Dalmanitina* Beds. There " is no sharp lithological boundary " between the sandstone and the *Tretaspis* mudstones below (p. 427), and although the sandstone contains *Dalmanitina mucronata*, which is the characteristic fossil on the *Dalmanitina* Series, the sharp break at its top decided the authors to draw the Ordovician-Silurian boundary at that level. *D. mucronata* has been found in the Ordovician *Tretaspis* beds elsewhere in Sweden. It is more in accord with British experience to assign beds with *D. mucronata* to the Ordovician.

The *Dalmanitina* beds are 2·38 m. (7·8 feet) thick, and are divisible into three parts ; the basal portion about 1 m. in thickness consists of crystalline, richly fossiliferous limestone with thin, sandy, and marly beds towards the top. The shale chips which are abundant in the bottom part, extend up to about 10 cm. The middle portion consists of fine sandy calcareous mudstone alternating with grey fine-grained sandy limestone ; this is a little more than 1 metre and passes up into ·3 m. of a grey fine-grained calcareous sandstone and siltstone. At the top " the calcareous sandstone is yellowish grey, rusty, and weathered, and delimited from the overlying beds by an uneven denudation surface " (p. 346). Fossils occur in the uppermost portion only of this sandstone.

There is an obvious hiatus at the top of the *Dalmanitina* beds also, and special interest therefore attaches to this contact and to the age and lithological character of the lowest portion of the succeeding *Rastrites* beds. The shales for 50 cm. above this contact at 32·76 m. consists of fine bedded dark mudstones with some lighter layers and a concentration of pyrite quite near, but not at the base. The lowest 7 mm. of this mudstone " is mixed with washed-up debris from the sub-stratum ; it is yellowish-grey with numerous rusty spots ". This description and that of the top of the

sandstone of the *Dalmanitina* beds clearly indicates that the lithological break between the *Rastrites* and *Dalmanitina* beds is complete, and where this happens it is impossible to judge from the appearance at the contact of the magnitude of the break or to forecast into what degree of unconformity it may develop in other areas. The concentration of pyrite associated with rusty washed-up debris is a familiar phenomenon near the base of the Silurian *Glyptograptus persculptus* zone) in Central Wales. At Kinnekulle, *G. persculptus* was not found, but some of the *Climacograpti* that are associated with it in Wales and pass up from that zone into the overlying zone of *Akidograptus acuminatus* are described. The lithology of the lowest *Rastrites* beds also compares rather with the basal part of the *A. acuminatus* zone than with that of the *G. persculptus* zone. It is probable for these reasons that the lowest beds of the full Silurian graptolite succession of Britain is missing at Kinnekulle above the hiatus. This may be compared with the succession in Ashgill quarry in the Lake District, where the lowest Silurian consist of beds above the *A. acuminatus* zone which rest sharply upon Ashgill Shales ; in many parts of that area the *A. acuminatus* zone is absent. I am of the opinion, therefore, that in comparison with the British sections the Ordovician-Silurian boundary should be drawn between the *Rastrites* beds and the *Dalmanitina* beds at a level 32·76 m. in the borehole. Difficulties have been experienced in determining the relations between the *Dalmanitina* beds and the *Rastrites* beds in various parts of Sweden. " The upper boundary of the *Dalmanitina* beds has not been definitely fixed. Graptolite shale belonging to various zones of the *Rastrites* beds usually form the upper boundary " (p. 459). It is partly for this reason that the opinion is held by Swedish geologists that the shelly facies represented by the *Dalmanitina* beds replaces laterally various horizons of the graptolitic shales. It would appear, however, in view of the clearly defined haitus in the Kinnekulle section that another interpretation is possible which would more satisfactorily account for the varying relationships observed between the *Rastrites* shales and the *Dalmanitin* beds in different parts of Sweden.

Only a few of the features of interest in the remainder of the Silurian section are mentioned. Between the Middle Llandoverian zone of *Monograptus convolutus* and the Lower Llandoverian shales at some distance below them, intervene about 1 metre of unfossiliferous limestones, but due to core losses of up to 50 per cent little information of their exact relationships to the beds above and below could be got. It is evident, however, that there is a considerable gap in the faunal succession at this level. There is no trace of the zone of *Monograptus triangulatus* with its various bands ; and it is almost certain that the zone of *Monograptus cyphus* is also missing, with possibly also some of the underlying zone of *M. acinaces*. A part of that zone seems to be represented by *M. incommodus*, and the zone of *M. atavus* is indicated by *Dimorphograptus extenuatus*. In view of the careful examination which was made of the *Climacograptus* species in the borehole, it is remarkable that the well-known and widely distributed *C. törnquisti* was not found. Although this species is most abundant in the *M. cyphus* and *M. triangulatus* zones it occurs also in the *M. acinaces* zone. Its absence at Kinnekulle probably confirms the magnitude of the break between the *M. convolutus* zone and the shales below. The Upper Llandoverian seems to contain a complete sequence of the zones from *M. turriculatus* to *M. crenulatus*, the British zone of *M. crispus* being obviously represented by *M. discus*. There is no evidence that the highest *Retiolites* beds reach to the base of the Wenlock. An interesting feature of the Upper Llandoverian is the occurrence of several thin bands of what is believed to be bentonite. This prompts a comparison with those recorded in several areas in the Upper Llandovery of Wales and the Welsh borders.

The University of Upsala and the Geological Institute are to be congratulated upon their enterprise in taking active and obviously highly successful steps to elucidate further the famous Lower Palaeozoic sections of Sweden. I wish it were possible to infect British Universities with their enthusiasm. O T. J.

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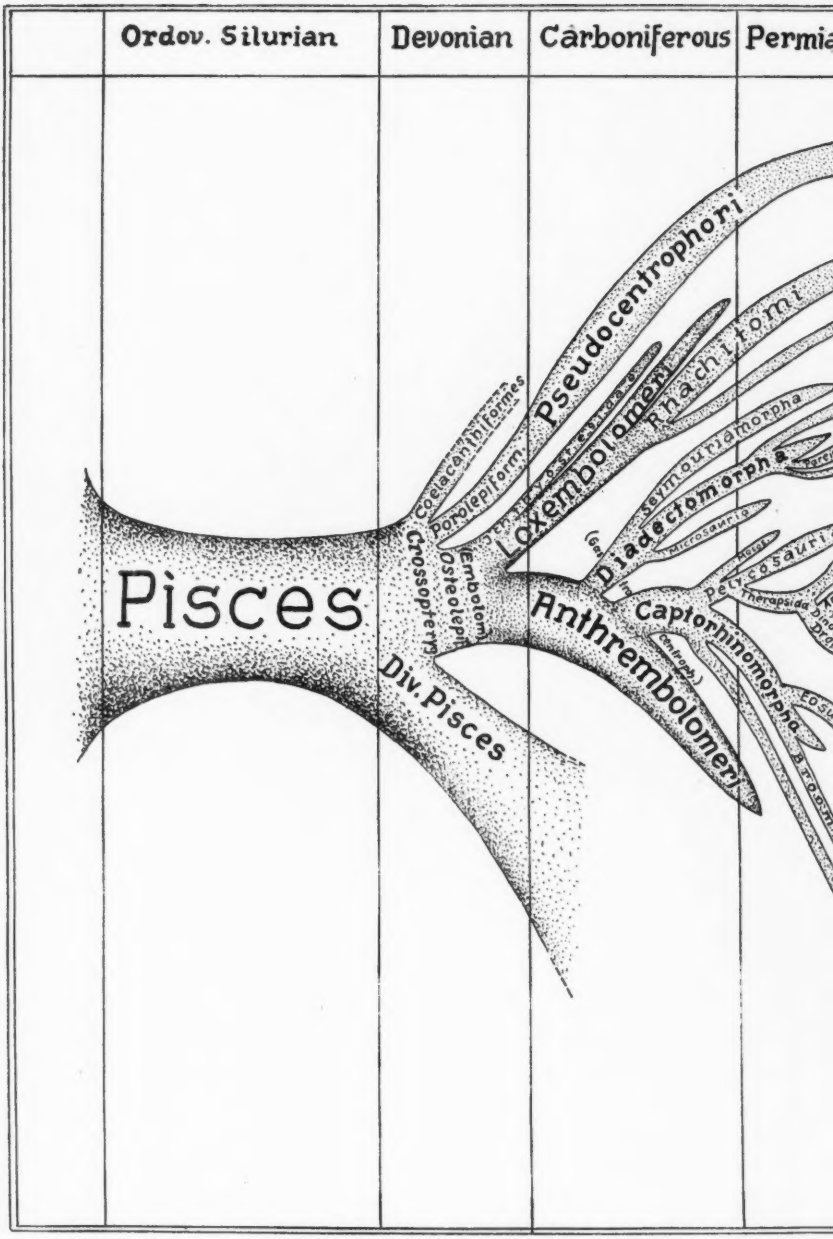
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